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Pattern-Making for Hand Moulding Machines.*

By J. Lucas.†

Some foundries are well equipped with machines, and are doing good and useful work on them; others have the best machines that money can buy, and yet are not successful with them; most foundries have one or two machines which can be used for flat back or other simple jobs, but at other times they are lying idle or possibly rusting away.

The foundry of the future will need to be equipped with a variety of moulding machines, together with the necessary moulding boxes or flasks, and a staff of pattern-makers fully alive to the possibilities and needs of those machines, and able to make their patterns accordingly.

If the use of moulding machines is to become successful, then the question of suitable patterns has to be considered. Most patterns of light and medium weight can be successfully mounted for machine work; but it is necessary to get the right machine for the job, and then make the pattern to suit the machine. Some castings can be made by the machine and stripper-plate method, which the most skilled of loose pattern moulders would find difficult to mould.

If mechanical methods are to be successful in the foundry, money will have to be spent on pattern-making. The successful machine-shop manager paying £600 for a machine tool would not hesitate to spend another £600 if nesessary on tools and equipment to make that machine do its work. Compare this with the foundry proprietor, who very grudgingly agrees to pay £50 or £60 for a moulding machine, and then objects to paying for a set of interchangeable moulding boxes and patterns mounted suitably for use on the machine.

There are many different types of moulding machines; hand-rammed pattern-drawing machines, squeezer machines both hand and power, jolt-ram pneumatic machines, hydraulic and other kinds. The writer, however, proposes to deal particularly with patterns suitable for hand-rammed pattern-drawing machines.

We usually associate the name of pattern-maker with a worker in wood, but it must be borne in mind that the metal pattern-maker is a very important personage in any establishment which aims at the successful use of moulding machines. Before mounting any pattern, it should be given exhaustive study as to ways and means and costs, or otherwise one may spend a large sum of money on a pattern plate, only to find it unsuitable for the intended moulding method.

Fig. 1 shows a turnover machine, a very useful type for all light and medium-sized castings. Different makes of this type have distinctive features. One machine has the table planed on both sides to a parallel thickness, and as such serves the purpose of a pattern plate; split patterns can be mounted directly on it. Where pattern plates are used, they are bolted on the top of the machine table *a*, the moulding box placed in position and fixed by the clamps *b*. After the box is rammed up, the table is turned over, leaving the moulding box hanging underneath the table; the lower table *c* is then raised by means of the lever *d* on the left-hand side of the machine, until it comes in close contact with the moulding box. While holding the lever down with his left hand,

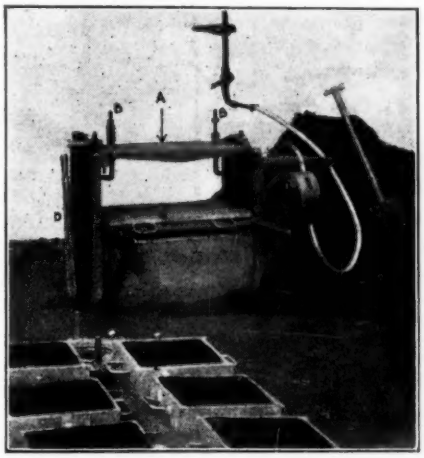

FIG. 1.

the operator, with a mallet in his right hand, releases the two clamps, and then with several sharp raps on the top table *a*, gradually lowers the lower table *c*, and by the force of gravity the mould lowers away from the pattern. With this method it will readily be seen that there must be no badly-fitting boxes, otherwise the mould will be likely to hang, with disastrous results. Some of these machines are made with the top table having a vertical movement, while the lower table is fixed so that the pattern is drawn away from the mould in the same direction that a loose pattern is drawn. These turnover machines are to be recommended for patterns having deep recesses, or difficult draws, which it would be impossible to get clear off a straight-draw machine.

* Read before a joint meeting of the Institution of British Foundrymen and the Leicester Association of Engineers, at Leicester, June 24, 1920, Mr H. H. Moore in the Chair.

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Fig. 2 shows the patterns of two cast tooth wheels *a*, with their respective stripper plates *b*. The teeth on these patterns are 3 in. deep, and are perfectly square, no taper of any description being allowed. It would be impossible to draw patterns of this type from the mould and guarantee that the teeth are not broken or cracked in the mould; but this trouble can be overcome by means of stripper plates, such as here shown. The patterns are fixed to the table of the machine, the stripper plate placed in position, the moulding box placed on, and by means of screws and plates, the stripper plates are fixed to the moulding box handles. When the box is lowered away from the pattern, the stripper plate comes away from the pattern along with the box, and so holding down the sand, guarantees a clear and accurate draw. These patterns are used on turnover machines, as they have deep recesses which are difficult to get

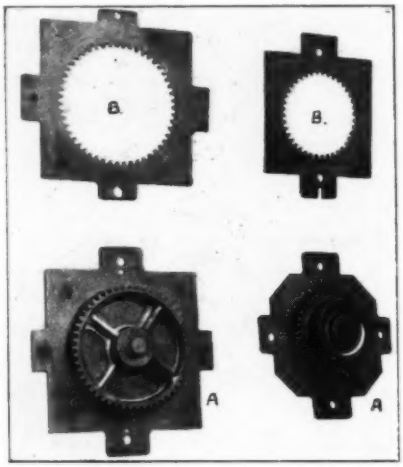

Fig. 2.

clear off a straight-draw machine. The patterns are of iron, and the stripper plate is formed by running babbitt metal round the teeth of the pattern and into a cast iron frame.

Fig. 3 shows another stripper plate method used on a turnover machine. This is a wheel of about 2 ft. in diameter, and the type of stripper plate shown in the previous picture would hardly be suitable on account of its large diameter and consequent liability of springing. This pattern is built up chiefly of wood, the spur-ring portion *a* being of iron. It is so constructed that the spur-ring is drawn upwards into the pattern itself. The moulding box is placed on the pattern, as it is here shown fixed to the machine table. After ramming up the machine table is turned over in the usual way, then a few turns on the hand wheel *b* will draw the spur-ring upwards from the mould. The mould *c* is then lowered from the rest of the pattern by means of the bottom table in the ordinary way. On referring to the mould, it will be noticed that the recesses *d* of this pattern are very deep, but with a turnover machine, and a fair taper on the pattern, accurate and clear draws can be obtained.

Fig. 4 shows a three-parted box job made on a turnover machine. The illustration shows the pattern. The sheaves are about 2 ft. in diameter, and the patterns are built up of wood with the exception of the loose flange *a*, which is of iron. The bottom part of the mould is made off the pattern *b* to the left of the picture. The top and middle parts are made off the pattern *c* to the right of the picture, the method of operation being as follows:—The pattern is bolted to the

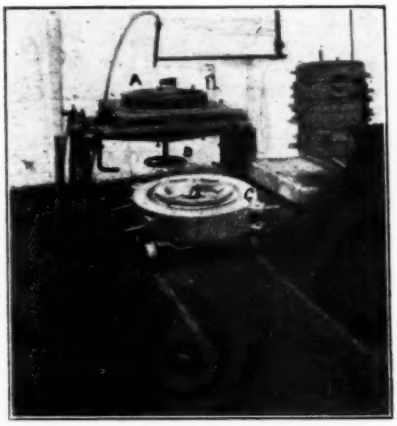

Fig. 3.

machine table and the middle part placed on the pattern and rammed up, the joint made and covered with parting sand in the ordinary way. The top box is then placed on, clamped to the table and rammed up. The table is then turned over, the clamps removed, and the top and middle parts with the loose flange *a* between them are then lowered away from the pattern. The middle part is then lifted off, the loose flange removed, leaving the top part ready for carrying away to the pouring floor.

This method was found very satisfactory, and we were able to produce castings far quicker by this method than would have been the case had a loose pattern been employed, while the pattern, although having several hundreds of moulds taken off it, showed scarcely any signs of wear. A loose pattern would have needed renewing several times to obtain this same quantity.

Fig. 5 shows a pattern of an internal cast gearing, mounted on another type of turnover machine, that type of machine where the pattern is drawn

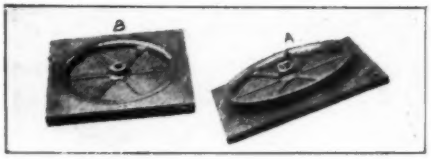

Fig. 4.

upwards from the mould in the same way that a loose pattern is drawn. (The table of the machine shown has been purposely tipped to give a better view of the interior of the pattern.) The inside part of this pattern is made separate from the

outer portion, and so constructed that it will work up and down the teeth portion.

The method of drawing the pattern is as follows. After the mould has been rammed up, a plate is placed across the mould and over the pin bolt *a*, shown extending from the core print on the

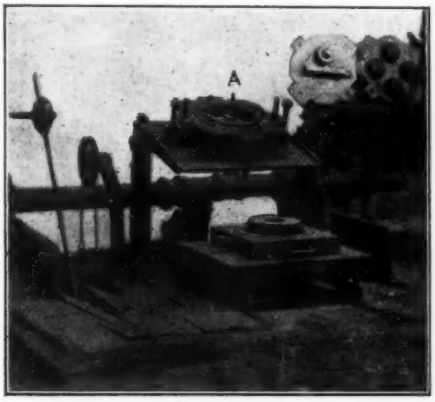

FIG. 5.

pattern. A nut is then screwed on the pin bolt and tightened up. The table is then turned over and the mould and pattern are separated in the usual way, but the inside portion of the pattern comes away with the mould, being bolted to it, and so forms a stripper plate, guaranteeing a clear draw of the teeth. This part is then unscrewed and drawn off the mould by hand.

We may next consider the straight draw type of machines, where the mould is separated from the pattern either by lifting the moulding box off the

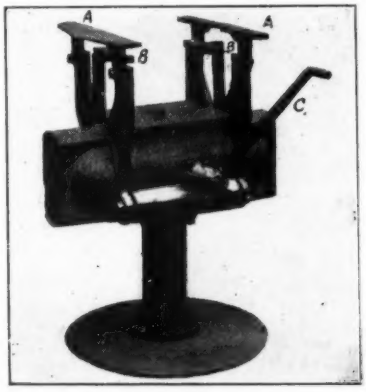

FIG. 6.

pattern, or by supporting the moulding box, and drawing the pattern away from the mould.

In one machine of this type the pattern plate is fixed, and the mould is lifted off the pattern by means of four stools. The moulding box is placed over the pattern and rammed up, and by means of a lever four lifting pins operate, which should be so arranged as to catch all four corners of the moulding box at the same time, and gradually lift the box off the pattern. This type of machine is not an ideal one for stripper plate work, but external stripping can be done. When the lifting pins are raised they should come into contact with the stripper plate and lift that off along with the moulding box. This is rather awkward, as the operator has to take care of the moulding box and the stripper plate at the same time.

The next straight-draw machine, Fig. 6, is very useful for all kinds of stripper-plate work. The moulding box remains stationary on its supports *a*, while the pattern plate is fixed to the movable part of the machine, the tee uprights *b*. After ramming up the mould, the handle lever *c* is brought over from right to left, and in so doing draws the pattern away from the mould. The flat table *d* makes an ideal support for any stooling arrangement for internal stripping, though the writer prefers, in patterns of this description, to fix the stooling plate to the external stripping plate, wherever possible.

Fig. 7 shows a group of pattern plates where the patterns are of such a nature that the joint line must be uneven, and consequently a cast pattern plate must be made. There three cast pattern plates were successfully used with a straight-draw machine as seen in Fig. 6. They are of cast iron, while the patterns are of a non-shrinking white metal composed of 85 lead, 5 tin,

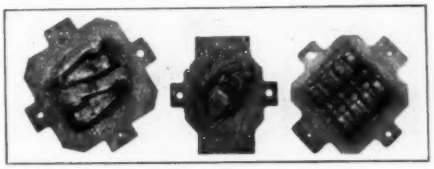

FIG. 7.

and 10 antimony. The cast-iron pattern plate is cast with the centre portion cored out, the edges of the core being formed V-shape, to give a hold to the white metal. The pattern plate is then planed to correct parallel thickness, and the holes jig-drilled to suit the moulding-box pins. The loose patterns are rammed up in a moulding box in the orthodox manner, taking care to ram the mould very hard, preferably using French moulding sand, or Mansfield Red sand, and facing the mould with French chalk. Before finally closing the mould, the cast-iron pattern plate is placed between the two halves of the mould, and located in proper position on the pins. The mould is closed and clamped, and the metal poured in, taking care not to pour the metal too hot, but using large runner heads. The pattern plate can be taken out as soon as cool, and if the mould has been properly made and the metal is alright, a good brushing with a wire brush will be all that is required, beyond cutting off the runner and risers, to put the pattern into work.

There are some foundries who make their cast pattern plates of aluminium. Such pattern plates are chiefly used with squeezer machines, where both tops and bottoms are rammed at the same time, and where the pattern is drawn by hand. In such cases the weight of the pattern plate is an important factor, hence the use of aluminium.

Fig. 8 shows two more patterns *a*, with their respective stripper plates *b*, the one to the left of the picture being a casting produced with an entirely square outer edge for chucking purposes in

machining. Without a stripper plate this would be impossible. When making patterns like these, the thickness of the stripper plate must always be taken into consideration, and the pattern above the pattern plate made that much thicker. These patterns are ideal patterns for the straight-draw machine, representing the use of the external stripper plate.

Fig. 9 shows two patterns, with the external stripper plate, the stools and the internal stripper

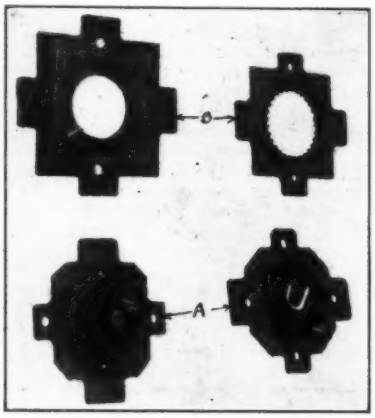

Fig. 8.

plate. The pattern to the left-hand is of eight cast-iron blocks about 2 in. square, and with 1 in. cored hole in the centre. The pattern is so made that any length of casting between ¼ in. and 2½ in. can be made, simply by regulating the distance between *a* and *b*, for which a set screw and locking nut underneath the pattern plate is provided.

The pattern to the right of the picture is of eight gun-metal flanged bearings, having about a ⅜ in. cored hole. The flanges are kept with a square edge and drawn through a stripper plate, and the cores also are stripped by means of the stooling arrangement. The arrangement of both these patterns on the machine is the same. The plate *a* is a fixture, and is therefore fixed to the fixed side arms of the machine. The plate *c* is also a fixture, and as this plate must be set in very accurate relation to *a*, it is so set by means of distance bolts and stays to *a*. To the plate *c* are fixed the stools *d*, which support the round centre cores when the

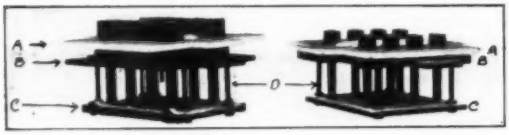

Fig. 9.

patterns are being drawn. These stools require most careful attention and must be accurate in height, otherwise, if they are too short, when the mould is closed there will be a crush, resulting in dirty castings: or, if the stools are too long, there will be a flash, with possibly a resultant blown casting. The pattern plate *b* is fixed to the movable side arms or tee uprights of the machine, and it is to this plate that the patterns are fixed. The fine degree of accuracy required will be realised when it is noted that the outside of the pattern works through the stripper plate *a*, while the inside works over the stools *d*. We have made castings

Fig. 10.

off these patterns up to 2½ in. in length, with a green sand core of 1 in. diameter.

Another very complicated type of pattern is shown in the next picture, Fig. 10. At the foot of the machine is shown a casting off this pattern,

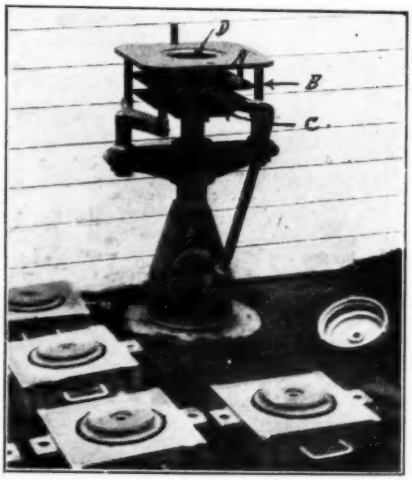

Fig. 11.

and one casting is here for your inspection, which will give you some idea of its shape, etc. The casting is an internal gear case used for a triple-gear type of pulley block. The cast gearing is of a very fine pitch, 66 teeth 9 pitch, and is required of great accuracy. It has to pass very careful

tests, and therefore must be most carefully moulded. The pattern is here seen mounted on the machine, which has been tipped forward to show the inside of the pattern to better advantage. The front moulding box locating pin has been removed for the purpose of the photograph; the back pin is seen in the illustration. The pattern

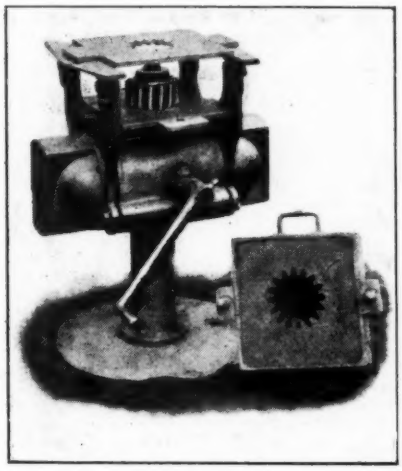

FIG. 12.

itself is built up of many parts, and is made to strip, both internally and externally.

Fig. 11 shows the pattern drawn, and gives a better view of the construction of the pattern. The top plate *a*, which supports the moulding box, is the external stripper plate, and takes care of the outside rim of the casting The centre plate *b* is the internal stripper plate, and supports that portion of the pattern which remains stationary, which in its turn supports the fine teeth of the

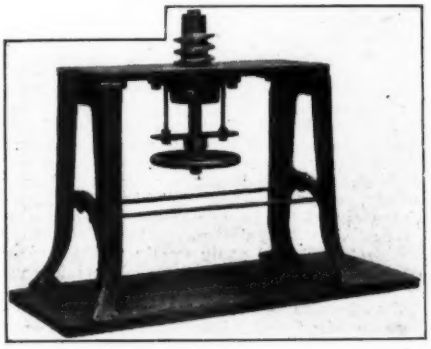

FIG. 13.

mould; it is that portion *d* which is seen coming just level with the top of the external stripper plate. The lowest plate *c* is the pattern plate, to which is fixed the outer rim of the pattern and also the centre portion of the pattern, that part with the centre boss and core print. The pattern was most carefully thought out and accurate drawings made of it, before the making was put in hand. All the parts are made either of cast iron or gun-metal. The outside rim is of cast iron, and made sufficiently deep to allow for the free working of the stripper for the teeth, and also to fix to the pattern plate. The required number of teeth were cut in internally, then the stripper for the teeth was made of gun-metal, its shape at the top being machined to the correct profile required for the shape of the casting, and then teeth were cut in externally to fit into and work up and down the outer rim of the pattern. This part was made sufficiently long to allow the outer rim of the pattern being drawn clear of the top stripper plate. The remaining part of the pattern, the centre boss with the core print, is made of cast iron, turned to fit accurately the gun-metal ring which forms the internal stripper, and is then fixed to the pattern plate. This pattern, like all the preceding ones shown, though built up of many parts, is so constructed that it can be attached to the moulding machine in a very few minutes, only six set screws being required.

Where stripper plates are used with patterns, a clear and accurate draw is always obtained, pro-

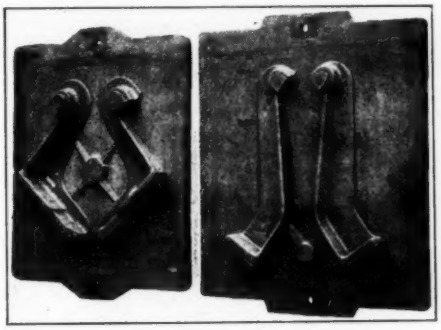

FIG. 14.

vided that the pattern is in proper order, having no blurred edges, nor being cold and clammy; so that apart from the stripper plate itself being a necessity in cases of quite square faces, it is extremely useful in assuring accurate draws in cases where the pattern has on its faces a variety of shapes or recesses.

The next illustrations deal with two jobs which it would be very difficult, if not altogether impossible, for a loose-pattern moulder to draw by hand. Fig. 12 shows a cast skew-gear wheel mounted on the machine, with pattern plate, stripper plate and pattern. The pattern plate is fixed to the movable side arms of the machine; the stripper plate is fixed to the fixed side arms. The only way to draw this pattern out of the mould is by a twisting movement. It is in such cases as these that the mechanical method will always have the advantage over the hand method. In the pattern shown this twisting movement is provided for in the method of fixing the pattern to the pattern plate. Instead of being fixed rigidly to the pattern plate a centre pin only is used, on which the pattern is free to revolve, and so, as the pattern is drawn from the mould through the stripper plate, it is free to revolve sufficiently on its centre pin to allow of it leaving the mould quite clear and free. The illustration shows the pattern as it is when drawn, and at the foot of the machine will be seen a mould off the pattern.

Fig. 13 shows a cast tooth worm, mounted ready for receiving the moulding box and ramming up. If this pattern were made as a loose pattern there is no doubt that it would be made in halves and moulded horizontally, with the result that a joint would be shown right along the casting, giving disastrous results in the working of the worm and the worm wheel, to say nothing of the probability of obtaining an oval casting. With a pattern as here shown these difficulties are overcome, and a casting with no joint at all across the teeth is obtained. The worm portion of the pattern is twice as long as required. That portion not required for the actual moulding portion of the pattern is hidden in the cast iron boss shown underneath the pattern plate. This boss is bored and screwed to accurately fit the thread on the pattern.

All the foregoing patterns are very costly to make, and their expense in most cases could only be justified by the fact that huge quantities are required off them, but there are heaps of cases where patterns mounted on plates

FIG. 15.

can be quite easily made in wood at a very little cost in excess of the cost of a loose pattern, while the life of the pattern would be considerably longer on a plate than loose.

Fig. 14 shows the method of using reversible pattern plates. In the two cases one complete pattern is made in halves and the two halves are fixed on one side of the pattern plate, in such correct relation that both top and bottom parts can be rammed up off the one plate, and when placed together they correctly match up and produce a casting without any twist.

Fig. 15 shows two patterns which in the ordinary way would have involved a very difficult pair of pattern plates, but by the use of a half core box *a*, becomes a simple flat back, which can be mounted on any machine table without the use of pattern plates.

In the making of the joint and the drawing of the pattern, the pattern-maker has his opportunity of helping the moulder and simplifying some of his difficult operations. In this respect it is up to the pattern-makers to get out of the old-fashioned method of pattern-making, developing new ideas and new methods, and seeking to be an aid to the moulder.

New Method of Chemical Analysis.

MR. WM. ROY MOTT, Research Chemist for the National Carbon Company, presented at the recent meeting of the American Electrochemical Society a description of a carefully worked out method of detecting the several elements by means of the characteristics of the electric arc-action on compounds of these elements. The process is an extension of the method of flame tests by means of the spectroscope. Mr. Mott's apparatus is, however, much simpler than the spectroscope, and his procedure rapid and accurate. The essential apparatus consists of a carbon arc-lamp in a hood, so arranged as to project a magnified image upon a screen in a dark room. Usually a magnification of twenty diameters will answer, but for a few very dim arcs a lower power is advisable. The lamp is trimmed with solid carbons about 13 mm. in diameter, such as are commonly used in closed arc lamps. A cup about 10 mm. in depth and diameter is drilled into the top of the lower carbon, which is connected with the positive pole. The average weight of the sample used is 0.5 grm. Mr. Mott operated the lamp at 25 amperes and 50 (arc) volts, from a 110-volt line.

The phenomena obtained are flame-tip colour, sparks, smoke, odour, sequence of distillation, and especially the nature and colour of the deposit on the poles. A special vapour luminescence, near the positive crater, is characteristic of some elements; for instance, calcium gives a unique red. The colours of the flame tip above the arc are tests for sodium, lithium, boron and copper. Iron produces a display of scintillating sparks from the negative carbon for several seconds after breaking the arc. Smoke is not as a rule a delicate test, but the emission of smoke from the hot upper tip on breaking the arc is a very delicate test for molybdenum, as Mr. Mott has not found a similar effect given by any other element. The odour aids in detecting arsenic, bromine, iodine and tungsten. The colour and shape of the deposit on the upper carbon are excellent points for classification. The method affords a form of fractional distillation at high temperatures, and of great range from mercury which boils at 257.2 deg. C. to tungsten which boils at 6,000 deg. C.

The new methods of analysis, using the arc images, are, we are told, simple, quick, delicate, automatic, semi-quantitative and comprehensive. Good tests are given for sixty-five elements. Any of these can be quickly and easily identified, it is said, in a few minutes in their ores, alloys, oxy-compounds, or in small, impure samples. The chief impurities are usually automatically discovered as the distillation proceeds. In mixtures of three metallic compounds—especially oxy-compounds — complete identification should be obtained in less than a quarter of an hour. The tests, so far developed, will identify on the average nine out of ten in unknown mixtures of any ten of these sixty-five elements. Very delicate tests (sensitive to 0.1 mg.) apply mostly to the uncommon, valuable, and refractory elements, which take so much time and skill to identify by the usual methods. In regard to halogen salts, the best procedure is to form oxy-compounds by alkali carbonate fusion, or other means. The tests as given apply directly to all ores, minerals, refractories, oxides, oxy-compounds, carbides, metals and alloys.

Future developments should lead to an extensive use of arc-image analysis, as it supplements and aids all other means of analysis. It is much like a refined blow-pipe analysis in utilising coloured beads and deposits. It is like fire-assay in using metal-bead separations. It is like spectrum analysis in using coloured light. Finally, it is like micro-chemistry in utilising magnified phenomena.

Iron and Steel Institute.

Adjourned Annual Meeting at Sheffield.

The adjourned annual meeting of the Iron and Steel Institute was held on May 14 at the Mappin Hall of the Sheffield University, Dr. J. E. Stead presiding over a large attendance of members.

In the absence of the Vice Chancellor of the University (Sir Henry Hadow) Dr. Desch (Dean of the Faculty of Metallurgy) welcomed the Institute to the Mappin Hall and to Sheffield.

The following Papers were read :—

The Effect of Initial Temperature upon the Physical Properties of Steel.

By J. H. Andrew, D.Sc., J. E. Rippon, M.Met., C. P. Miller, B.A., and A. Wragg, B.Sc.

(*Summary.*)

In this Paper the authors have endeavoured, by the determinations of different physical properties and the rate of expansion above Ac3 is increased, up to a temperature depending on the carbon content increasing with this, above which temperature the expansion settles down to a rate similar to that of pure gamma-iron. This was found to be true for all steels tested.

In the course of a summary of their results and the conclusions based upon them, the authors remark that many of the effects of initial temperature on steels are already known. Besides such phenomena as excessive grain growth, variations of hardness of the product, etc., in the case of carbon, low-nickel, and low-chromium steels, there is also the lowering or suppression of the critical point of nickel, chrome, tungsten, and other steels, when cooled comparatively slowly. That the latter phenomenon also occurs with the aforementioned steels, when the rate of cooling is very much quicker, has been shown by Le Chatelier, Portevin, and others.

No direct measurement of any property above the critical range, which might conceivably account for

Table I.—*Summary of Behaviour of Physical Properties*

Critical point.	Thermal.	Dilatation.	Resistivity.	Magnetic.
		1.—*Slow Cooling.*		
Ar 3.2.	Evolution of heat.	Increase in vol. continuous with Ar1.	Fall in resistivity continuous with Ar1.	Slight change
Ar1	Evolution of heat.	Sudden expansion depending on carbon content and initial temperature.	Sudden decrease in resistance	Sudden increase in permeability
400°C. point in Ni-Cr steels	do.	do.	do.	do.
Low point at 150°–160° C.	Small evolution of heat	Large expansion independent of carbon content	Decrease in resistance	Increase in permeability
		2.—*Tempering.*		
Point at 100° C. ..	No change noted	Contraction with carbon greater than 0.6 per cent. when quenched above Ac3, 2, 1	Decrease in resistance	Slight increase in permeability
150°–300° C. ..	Evolution of heat	No change	Above change continues	Above change continues
300°–350° C. ..	Evolution of heat if gamma-iron present	Contractionneutralised by gamma-iron present	Sudden decrease in resistance if gamma-iron present	Sudden increase in permeability if gamma-iron present
500° C.	None	None	None	Increase in permeability

their variation with changes in initial temperature, to determine the actual significance of these changes, and to advance a hypothesis that will satisfy all their experimental results. The steels experimented with comprised 5 carbon, 7 nickel, 5 chrome, and 6 nickel-chrome steels, and the physical properties determined were as follows :—Thermal data, temperature resistivity data, temperature dilatation data, and magnetic temperature data.

Numerous heating and cooling curves are plotted by the authors in connection with their thermal data determination, and in dealing with their interpretation they point out that :—(1) There is a contraction on the alpha to the gamma change taking place (on heating), this being reversed on cooling in the form of an expansion. (2) (*a*) Up to a certain carbon content between 0.05 per cent. and 0.6 per cent. the curves show that above the Ac3 point the solid solution assumed a uniform rate of expansion, which does not vary appreciably with the carbon content between these points. (*b*) Above this carbon content, namely, 0.6 per cent., the above-mentioned effects of maximum initial temperature, has been measured till now.

The dilatometer results submitted show that a quantity "carbide expansion" can be measured, which is some indication of the state of the steel at the temperature at which it is measured, and of the behaviour of the steel on cooling.

Thermal resistivity and magnetic data give no obvious indication of this quantity *per se*, but only its effect on subsequent events. Thus while carbide, changing from the normal to the expanded state, has no effect on electric resistance and magnetic properties when in solution in gamma-iron, yet in a martensite, which has been shown to be essentially alpha-iron with expanded carbide, the resistance of the alpha-iron is considerably increased, and the magnetic permeability lowered by carbide in this state.

That the above effects are not due to gamma-iron in the hardened product has been pointed out in the resistivity, magnetic, and dilatometer sections, all of which agree in that small quantities of gamma-iron

in hardened steels can be measured by changes taking place when tempered above 300 deg. C.

The authors submit Table I., giving a summary of the behaviour of physical properties :—

Conclusions.

The authors' final conclusions are as follows :—

(1) The effect of variation in initial temperature upon the position of the resulting transformation points in certain nickel, chromium, and nickel-chromium steels has been determined.

(2) Thermal, dilatation, resistivity, and magnetic temperature determinations of all steels experimented with have been carried out.

(3) The volume change at the normal transformation points, as shown by the dilatometer, has been found to be composed of two changes working in opposition—(*a*) allotropic change, and (*b*) change due to carbide. The latter change in steels of high carbon content is not completed at the ferrite or carbide (SE) line, but continues to a temperature depending on its composition, particularly carbon content, increasing with this. This quantity has been shown to be a measure of the molecular concentration of the carbide in solution, and controls the temperature at which the allotropic transformation takes place.

(4) Quenching merely stereotypes the condition of the carbide, which, in its turn, controls the allotropic change.

(5) This variation in the molecular concentration is readily explained by the assumption that carbide dissociates at and above the temperature of the normal transformation point.

(6) Nickel-chromium steels behave in much the same way as carbon steels, excepting that in the latter the time factor necessary to produce the same changes in the carbide is of a much lower order.

(7) Martensite has been shown to be the product formed when the allotropic change has been depressed by dissociated carbide, to a temperature at which the latter is able to exist as such in the alpha-iron formed. At the temperature of the normal transformation point martensite is not formed as an intermediate phase between austenite and pearlite.

(8) When the molecular concentration of the carbide is such that the allotropic change is depressed below atmospheric temperature, the resulting product will be austenite, *i.e.*, the iron is retained in the gamma state.

(9) By tempering austenite in such a way that the carbide becomes partially dissociated, the allotropic change is able to take place on re-cooling, forming martensite, thus explaining the phenomenon of secondary hardening.

(10) Electrolytic separation of carbides in a nickel-chrome steel, in which the transformation has not occurred at the normal temperature (600 deg. C.), shows, upon analysis, a total absence of chromium. This is additional evidence that the abnormalities of nickel-chrome steel are due to iron carbide, rendered more stable by nickel and chromium, in solution in the iron.

(11) Extensive tempering experiments have been carried out—*i.e.*, dilatation, resistivity, and magnetic—which enable the proportions of alpha- and gamma-iron in the quenched product of any steel to be determined.

(12) It has been shown that in the carbon steels experimented with, quenched at 1,000 deg. C., the iron in the product is in the alpha state. In alloy steels gamma-iron is present in various proportions, particularly with high carbon content. In extreme cases alpha is entirely absent.

MYSTERY ENGINE.—One of the ships delivered to Britain by Germany under the terms of the Armistice is equipped with an engine of new type, the working of which has to be discovered without assistance. The engine is described as "a double-acting marine Diesel engine," and is of very high-class workmanship, but contains evidences that it is experimental.

The Structural Constitution, Hardening and Tempering of High-Speed Steel containing Chromium and Tungsten.

By Kotaro Honda and Takejiro Murakami.

(*Summary.*)

In this Paper, which is an abstract from the 32nd Report of the Iron and Steel Research Institute of Japan, the authors explain that the object of the research was to ascertain (1) the structural constitution of the high-speed steel, that is, the form in which chromium and tungsten exist in the normal condition; (2) the change of these constituents during heating and cooling, and (3) the effect of these constituents upon hardening and tempering. The original investigation included the magnetic and microscopic studies of the specimens containing different amounts of chromium, tungsten, and carbon. The specimens were prepared by suitably alloying ferro-tungsten, ferro-chromium or metallic chromium, with two carbon steels in a magnesia melting-tube in a Tammann furnace, or in a graphite crucible lined with magnesia in a wind furnace. The specimens used may be divided into three series: Series I., in which tungsten and chromium were nearly constant, whilst the percentage of carbon ranged from 0.33 to 1.26 per cent. Series II., in which tungsten and carbon remained approximately constant, whilst chromium varied from 0 to 7.35 per cent. Series III., in which chromium and carbon were nearly constant, whilst tungsten varied from 0 to 18.80 per cent.

The results of the investigation may be summarised as follows :—

(1) In an annealed state, a high-speed steel containing about 5 per cent. of chromium, 18 per cent. of tungsten, and 0.6 per cent. of carbon consists of iron dissolving tungstide, free tungstide and carbides, Cr_4C and WC, in a free state.

(2) If the steel be heated above the Ac1 point, the carbides dissolve in austenite, and further undergo the following change :

$$2Cr_4C = Cr_7C_3 + 5Cr.$$
$$2WC + 3Cr + 4Fe = 2Fe_2W + Cr_3C_2.$$

The higher the temperature the more these changes proceed from left to right; but in the normal cooling from a high temperature the reverse change goes on slightly, and therefore at room temperature we have a steel containing the carbides, chromium, and tungstide, all in solid solution, that is, a hardened steel.

(3) The high-speed steel shows the lowering of the transformations during cooling from a sufficiently high temperature. The self-hardening is intimately related to the lowering; the larger the lowering, the more the transformation is suppressed. Hence we can study the self-hardening property by the lowering of the transformations.

(4) During heating, a hardened steel increases its magnetisation by the separation of the carbides from the solid solution, that is, by tempering. Hence we can conveniently study the degree of tempering by means of magnetic heating curves.

(5) The tempering of a hardened high-speed steel takes place in two steps, that is, at about 400 deg. and above 700 deg.

(6) The self-hardening and the resistance to tempering principally depend on the quantity of dissolved Cr_7C_3 in iron containing chromium and tungstide; and hence these increase with the contents of chromium and carbon conjointly. These properties also increase with the maximum temperature, or the rate of cooling.

(7) Tungsten in high-speed steels diminishes the maximum temperature at which, during cooling, the self-hardening property of the steels begins to take

place. Tungsten exceeding 12 per cent. exists as fine globules of tungstide Fe_2W, and these behave in tool steel like saw-teeth in increasing the cutting efficiency rather than intensifying its hardness.

(8) The fine globules of the tungstide are easily coloured brown to black by immersing the specimen in a cold alkaline solution of ferricyanide for 10 to 15 secs.

(9) The tungstide in high-speed steels segregates as a eutectic during cooling from the melt. In a tool steel the globules of the tungstide must, however, be uniformly scattered over the whole mass.

The Properties of Iron-Chromium Carbon Steels.

I.—THERMAL ANALYSIS.

By Professor C. A. Edwards, D.Sc. (Manchester University), H. Sutton, M.Sc., and G. Oishi.

(*Summary.*)

The object of this Paper is to describe the thermal critical points, and more especially the A1 changes, of a number of iron-carbon-chromium alloys, as revealed when the rate of heating or cooling is very slow, and to record the effects of varying known rates of cooling and initial temperatures upon the carbide changes, as well as their influence on the hardness of the material. The work may therefore be regarded as an extension, to a fairly wide series of alloys, of an investigation which was published in 1916 by Prof. C. A. Edwards, J. N. Greenwood, and H. Kikkawa on a steel containing 6.15 per cent. of chromium and 0.63 per cent. of carbon. The specimens used were cubes of 1-in. side except in a few instances where the quantity of available material would not permit of such large specimens being taken, when pieces of 1-in. by 1-in. by ½-in. were used.

The temperatures at which the carbides go into solution when the steels are heated and those at which the reverse change takes place on cooling have been carefully determined. These have been tabulated by the authors, and also diagrammatically illustrated in a ternary diagram. The results very clearly indicate that the temperature at which the carbides separate from solution during cooling is raised by an increase in the chromium and carbon content of the steel. In considering any particular series of alloys in which the carbon content is constant on the one hand, or the chromium is constant on the other, the separation of the carbide occurs at the highest temperature when the percentage of chromium is approximately ten times that of the carbon. The temperature of this thermal change increases as the chromium and carbon content is raised along a line, in the ternary diagram, which corresponds with alloys containing about 10 of chromium to 1.0 of carbon.

After considering Arnold and Read's analytical results for the carbides that were separated from annealed steels, the authors conclude that there is a double carbide having the formula $Fe_3C.Cr_3C_2$. With annealed steels containing less chromium than is required to combine with the carbon to form the above carbide, practically none of the chromium exists in solution with the iron. When the percentage of chromium is greater than is required to form $Fe_3C.Cr_3C_2$, some of the chromium, increasing with the total chromium content, remains in solution with the iron after the carbides have separated from solution on passing through the Ar1 change.

In view of the fact that some of the chromium in excess of that required for $Fe_3C.Cr_3C_2$ is found in the carbides, and the remainder is held in solution with the iron, it follows that the chemical nature of the carbide changes as the chromium increases above $\frac{Cr}{C} = 4.3$. At present the evidence is not sufficient to permit of any definite conclusion being drawn as to the composition of the new carbide. If, however, there is no such carbide as Cr_4C, the authors think that Cr_4C_2 must be present when there is sufficient chromium in annealed steels. For the whole of the carbon to be combined as Cr_3C_2, in annealed steels, it would be necessary to have a comparatively large excess of chromium present, because so much of that element remains in solution with the iron. On the basis that Cr_4C_2 is present in these steels, it would be necessary to suppose that this carbide will hold a considerable quantity of iron in solid solution to make it fit in with Arnold and Read's analytical data.

The influence of initial temperature on the critical cooling velocities has been determined for a large number of the specimens. From this point of view the alloys are most conveniently divided into two distinct groups, as was indicated by Murakami. First, those containing more carbon than $\frac{Cr}{C}$ = approximately 10, which possess similar hardening characteristics to ordinary carbon steels, and second, those containing more than this ratio of chromium, which have much slower critical cooling velocities. The boundary line dividing these two groups is not very clearly defined, but the irregularities in this respect are considered to be due to the influence of varying quantities of impurities, more especially manganese and silicon. It seems quite impossible to account for this natural subdivision of the alloys without considering that there is a compound corresponding in composition with the line in the ternary diagram, for a carbon to chromium ratio of 1 : 10.0. Without in any way wishing to make a definite conclusion regarding the compound in question, the authors tentatively suggest it is Cr_7C_3.

Whether the increased facility of hardening, which is brought about by heating alloys of the second group to high temperatures, is due to the decomposition of Cr_4C_2 into Cr_7C_3 and chromium, or merely to the presence of an excess of chromium retarding the precipitation of the carbide from solution, it is at present impossible to say. In fact, the true explanation may be found to be something entirely different. Before this problem can be solved much more experimental work will be necessary.

The Structure of Some Chromium Steels.

By J. H. G. Monypenny (Chief of the Research Laboratory, Brown, Bayley's Steelworks, Limited).

(*Summary.*)

During the past few years the author has investigated the structures and properties of a large number of high-chromium steels for commercial purposes. The results obtained from these steels have shown that the structures produced by varying conditions of treatment are not always in agreement with opinions, probably widely held, which are based on previously published investigations. In many cases facts have been brought to light, which, so far as the author is aware, have not been previously published. In all cases, the steels examined were made on a commercial basis, either in the open-hearth furnace (25-ton), electric furnace (either 25-cwt. or 7-ton charges), or crucible furnace (50-lb. and 100-lb. ingots). In the two former cases the samples examined were from bars 1⅛ in. diameter, rolled from 12-in. ingots, except that in certain high-chromium steels a number of small, flat samples (5 in. by 1½ in. by ¾ in., such as are used for analytical purposes) were examined in the cast condition. The author's work shows that with chromium steels containing between 1.5 and 15 per cent. chromium :—

(*a*) The effect of increasing amounts of chromium on the properties of steel is progressive; there do not

appear to be boundaries which mark out ranges of composition where the properties change suddenly. Probably the most abrupt change is in the production of austenite on quenching from high temperatures, the limiting compositions giving this constituent being fairly sharply defined. No evidence has been obtained that chromium steels can be divided up into a number of areas of composition, the properties of which differ from each other owing to the presence of different double carbides.

(*b*) Part of the carbide forming the pearlite in the annealed or tempered condition does not dissolve at Ac1, but progressively during a considerable range of temperature above this point. While this behaviour suggests the presence of two distinct carbides, no microscopic evidence has been obtained of the presence of different carbides in the annealed samples. It is very probable that it is the solution of this carbide which gives rise to the very great increase in the hardening properties of chromium steels in the range in which it dissolves. As, however, the increase in hardening property continues after the carbide has all dissolved, it is probable that dissociation takes place in the dissolved carbide in a manner similar to that suggested by Edwards.

(*c*) The rate of diffusion of carbides in chromium steel is much slower than in ordinary steel, and hence a much longer time is required to produce equilibrium at any given temperature than with steels free from chromium.

(*d*) Chromium lowers the carbon content of the eutectoid point considerably. It also decreases the solubility of cementite in austenite. The approximate position of the eutectoid point and of the solubility curves of the carbide (under definite conditions of heating) have been mapped out.

(*e*) The properties of austenitic chromium steels are of great interest theoretically, since they afford proof that martensite is the first stage in the decomposition of austenite.

The author has not set out a theory of the constitution of chromium steels; in his opinion much more work is required in clearing up a good many points before a satisfactory theory can be evolved.

Discussion of Papers.

After a short introductory address by the PRESIDENT, in which he reviewed the industrial history of Sheffield in his own lifetime, the reading and discussion of the Papers held over for the Sheffield meeting was proceeded with.

CHROMIUM STEELS.

PROFESSOR C. A. EDWARDS read the Papers by himself and Messrs. H. Sutton, and G. Oishi and A. L. Norbury on Chromium Steels.

Dr. Andrew took it that all the analyses of complex carbides had been done on annealed steels. But had they the right to assume that the carbides existed in the quenched state in the same molecular forms in which they existed in the annealed state? With reference to the valency of carbon, they had no real knowledge as to the actual valency of a carbon atom in steels. Was it correct to assume that a carbon could combine with any number of atoms of any element? Could they have any variable valency in their carbon steel or could they arrange their atomic proportions simply as they wished?

MR. J. H. S. DICKINSON said Prof. Edwards' work with regard to the critical cooling velocities of steels very nearly confirmed some results of his own which he published in the spring of last year. The real use of nickel and chromium in steel was to get a critical cooling velocity which would cover a fairly wide range so that one could get similar hardening effects at different cooling velocities.

MR. HARRY BREARLEY admitted a distrust of all chemical formulæ relating to metallic compounds which were based on the analysis of residues. His opinion was that nearly the whole of the compounds which had been isolated as residues and analysed in order to fix their chemical composition were unreliable. The one exception was FeC_3 compound.

DR. HATFIELD admitted that Mr. Brearley was to some extent justified in the attitude he had taken up, but nevertheless the examination of residues constituted an easy and in his (Dr. Hatfield's) opinion, an empirically reliable method of obtaining knowledge of some of the constituents that obtained in steels. He personally had used it to some considerable extent and with advantage. There was one aspect of those residues that had never been brought forward in these discussions, and which was frequently overlooked. Those residues, whilst they might be homogeneous constituents, were not necessarily compounds, but they were undoubtedly in many instances solid solutions of one or more substances, and he thought that in too readily endeavouring to fix definite chemical formulæ for these residues they were perhaps going further than they ought to.

DR. THOMPSON thought the claims brought forward by Dr. Edwards and his collaborators were entirely justified. They did appear to prove beyond the shadow of doubt that until one came to a chromium carbon ratio of 4.3, the whole of the chromium present was there as a carbide. If that carbide was isolated from the solution, then it would have comparatively little influence on the resistivity, and the results therefore were in entire agreement with the conclusions which Professor Edwards had drawn.

DR. DESCH shared Mr. Brearley's distrust of chemical methods of attack, but when one had a residue which was not merely constant in composition when attacked in one way, but which when attacked by several different reagents and taken fractionally still always gave a constant result, there was, he thought, a theoretical reason for supposing that that represented a definite compound, but it was only under such conditions that such conclusion could be drawn.

In the course of his reply, PROF. EDWARDS said he and his collaborators had not in their work dealt experimentally with the analysis of carbides. They had been making the observation in quite other directions, and they had, so far as they had been able, to co-relate their data and that obtained by previous workers. He agreed with Mr. Brearley that it was very dangerous to make conclusions from analysis, but it would be seen that they were trying to attack the problem from as many points as possible. So far, they had only gone two stages, but the work was continuing.

MR. J. H. G. MONYPENNY next presented his Paper on "The Structure of Some Chromium Steels."

MR. HARRY BREARLEY said one point brought out in Mr. Monypenny's Paper had a certain amount of commercial significance; that was that when the three carbides in chromium steels (both the high-chromium and the low-chromium steels) were passing into solution they did so very slowly. That, he thought, gave the sort of evidence needed in order to form a very clear picture of why chromium steels were specially subject to suffusion. As the amount of free carbide went more and more into solution, so they got the suffusion phenomena more and more clearly expressed in the cooling curve until ultimately if they took the temperature of, say, 2 per cent. chromium steel high enough, they got it cooling down with no variation of heat in the cooling curve, and the material remained in the self-hardened condition.

MR. C. W. KAYSER said he had used many of the steels with a ratio of carbon to chromium of about 1 to 6 as turning tools or drawing dies, and it had been found that by tempering these at about 500 deg. C. the cutting efficiency or the drawing efficiency had been very much increased.

MR. MONYPENNY, in the course of his reply, said he was rather surprised at any chromium steel retaining its hardness after tempering up to a temperature of

625 and 800 degrees. He had never yet met a pure chromium steel, at any rate containing up to 15 per cent. chromium which was not very considerably tempered by just over 600 degrees. In the austenitic type of steel the hardness fell very rapidly. The maximum hardness occurred at about 600 deg. and then fell very rapidly after that.

EFFECT OF INITIAL TEMPERATURE UPON THE PHYSICAL PROPERTIES OF STEEL.

Dr. J. H. Andrew then presented the Paper, of which he was the author in conjunction with Messrs. J. E. Rippon, C. P. Miller, and A. Wragg, on "The Effect of Initial Temperature upon the Physical Properties of Steels" (see last week's issue, page 677).

Dr. Hatfield said the authors' theory that martensite was a solid solution of dissociated carbide in alpha-iron was extremely interesting, but it was contrary to the views held by many metallurgists. They all admired the authors' attempt to support their hypothesis, but there were alternative explanations.

Dr. F. Rogers would like to know where Dr. Andrew got evidence of the dissociation of carbides above the SE line in carbon steels; also could this dissociation be explained as being partially at least due to dissociation into elementary carbon or graphite? Dr. Andrew told them that they got no hardening in some of these steels until they had fallen below, say, 150 deg. C. The exact position of that temperature depended, of course, upon the particular steel and also upon the actual speed of cooling. In some cases the temperature might be actually below the atmospheric temperature. He could very strongly confirm that in some cases. The critical point in some of the quite common nickel-chromium steels, even on slow cooling, was down as low as 150 deg. C., and that point had certainly got to be exceeded in these steels before hardening proper set in—before, therefore, they could temper the steel at all, and that was the practical application of it.

Dr. Andrew, in reply to Dr. Rogers' remarks, thought they had proved definitely that they got dissociation, or what they called dissociation, in a 0.8 carbon steel. Some of the diagrams in the Paper showed signs of carbide expansion with a 0.8 carbon steel, and they also got it in nickel steels considerably below the eutectoid composition.

BRITTLENESS IN STEELS.

Dr. F. Rogers then presented his Paper on "Brittleness in Nickel-Chrome and Other Steels"

Mr. Harry Brearley said he was not at all convinced by any of the evidence that Dr. Rogers had adduced that he was on anything like the right lines. If Dr. Rogers attached any thermal value whatever to the curves he produced, he ought to have taken a piece of steel which had not got temper brittleness, and shown that he got an entirely different form of thermal curve. As far as he (the speaker) could make out, Dr. Rogers had not done any such thing. He had produced curves which had got a lot of curious wriggles in them, but who amongst them did not know the discussions that there had been about wriggles in curves which it had afterwards been found did not exist at all except in some idiosyncracy of the apparatus by which they were made? Also, he could not agree with Dr. Rogers that temper brittleness was more likely to be found in material which had been intensely hot worked. One did find a number of cases in nickel-chrome steels that had not got temper brittleness at all, and they could not induce temper brittleness in them. They might find one cast in ten, or one in a hundred, but they found a larger percentage of casts that had not got temper brittleness in steels made in the electric furnace than in steels made in the open-hearth furnace, and, generally speaking, steels in the electric furnace had been submitted, in the molten condition, to more intense heat than those in the open-hearth furnace. Dr. Rogers said that they were not likely to meet with temper brittleness in large pieces. But it was exactly in large pieces that temper brittleness was met with. Everybody who had anything to do with the manufacture of armour-plates would know that armour-plates suffered continually from temper brittleness. He ventured to say that any piece of nickel-chrome steel which was subject at all to temper brittleness could have temper brittleness evolved in it and developed in it no matter what condition it happened to be in—that was to say, whether it was hard or whether it was soft.

Mr. J. H. S. Dickinson agreed with Mr. Brearley in combating Dr. Rogers' remark that one was much more likely to get temper brittleness in small specimens than in large. He thought Dr. Rogers was perhaps on the track of something sound in referring to the effect of initial temperature in rolling or forging. He thought that was what Dr. Rogers claimed in producing what he (the speaker) should describe as a free disposition of temper brittleness. He found sometimes that one large forging out of a cast would give temper brittleness much more readily—or rather it would give a tough condition much less readily—than other forgings from that cast. And when he had found that he had generally found there was some evidence that the forging temperature had been in some way abnormally high.

Dr. Andrew gave some information as to the results obtained with phosphorus steels, two series of which were experimented with. The first series contained approximately 3½ per cent. of nickel, and 0.35 per cent. of carbon, and the manganese was approximately constant at about 45. The lowest phosphorus was 0.018, and the highest 0.152. The other samples were nickel-chrome steels, with phosphorus ranging from 0.01 to 0.058. He and his collaborator had not come to any definite conclusions, but it certainly seemed as if the phosphorus content had an important bearing on impact brittleness. In the nickel-steel series, the impact value, after slow cooling, was 90 in the case of the low-phosphorus steel, and only 1 in the case of the 0.15 phosphorus steel. But, with quenching from the tempering heat instead of slow cooling, while the low-phosphorus steel remained at 90, the highest-phosphorus steel impact was raised to 87. When they got a difference like that, he thought it was time to look to the element concerned.

Mr. J. H. G. Monypenny did not agree with Dr. Andrew's theory. Quoting from the records of actual works tests, he said they showed that phosphorus had nothing to do with the matter.

Dr. Rogers, in reply to the discussion, said all the leading metallurgists of the district had disagreed with his conclusions, but he would point out in reply that none of them had brought forward any heating curve data. As he had said, his Paper was only a pioneer one. The question of phosphorus was the most important that had been raised. As regarded the Brinell tests, he had no doubt the differences were due to some difference between his treatment and that which some of the other speakers used.

The President said Dr. Rogers had tried to solve a frightfully difficult question. He had made an honest attempt, and they could congratulate themselves on having had his ideas brought before them. He had no doubt the Paper would lead to more research, and they would eventually get to know the why and the wherefore of this peculiarity.

All the shares in the Wyndham Mining Company, Limited, having, as we recently announced, been acquired jointly by the Barrow Hematite Steel Company, Limited, and the Millom & Askam Hematite Iron Company, Limited, the former Wyndham directors have now resigned, and their places have been taken by Capt. W. F. Egerton (chairman), Mr. F. Holt, and Mr. G. Mure Ritchie. Mr. W. Selkirk has been appointed consulting engineer.

The Electric Furnace for Steel and Non-Ferrous Metals.

Before the Sheffield Branch of the Institution of British Foundrymen, on March 19, Mr. H. Greaves lectured on "The Electric Melting of Steel and Non-ferrous Metals." Mr. J. R. Hyde presided.

At the outset Mr. Greaves said he had been asked to give the comparative costs of the different types of electric furnace. Probably most of them would realise how difficult it was for him to do that. He was pretty well acquainted with the cost of operations of their own type, but he was not in a position to give reliable data about the operation of other furnaces. Besides, comparisons under those conditions would be unfair. The same type of furnace of exactly the same construction would give different results in different works. The conditions varied considerably. Often one was unable to see the cases in which the best results were obtained upon other people's furnaces, and it would be unfair to take the best case of one's own furnace and compare it with the worst for the other side. Therefore, he did not want to make any comparisons and would only endeavour to give the cost on the operations of furnaces which he knew more about.

Proceeding with his paper, Mr. Greaves said: Steel melting by the electric furnace has made very great progress in this country during the last six years, owing undoubtedly to the fact that high-grade special steels can be readily produced at competitive costs, and also because the electric furnace solved the problem of utilising scrap metal, in the shape of turnings, punchings, etc., and turning these into steel of all grades, and thus partly relieved the serious situation which had arisen due to the shortage of ordinary pig-iron and also of Swedish material necessary for crucible-quality steels.

Making steel by the electric furnace at one time was considered a very involved process requiring very expert knowledge, but the last few years has proved that steel can be produced by this method by men who have had practically no training beyond a small amount of tuition covering a period of two to three weeks after installing a furnace, both in this country and abroad. The writer has personal knowledge of quite a number of such cases where very successful results are obtained in foundries producing both castings and also ingots of plain carbon and alloy steels made to specification.

The electric furnace method of producing steel for castings, the writer ventures to prophesy, will be very largely adopted in this country in the near future, and has already made considerable strides in U.S.A., France, Italy and Belgium; and in countries where steel has not been a feature of commercial industry, they are awakening to the knowledge that the electric furnace presents to them a ready means of obtaining castings from the abundant scrap which up to the present has been dumped and considered of little value. Particularly is this the case where coal and coke are scarce, but where there is ample water power for generating the electric current.

The usual method of making steel in the electric furnace for castings is as follows: The scrap material to be melted is charged into the furnace along with sufficient hematite ore to oxidise all the carbon in the charge; 5 lbs. of ore for every lb. of carbon will usually be found to be quite sufficient unless the scrap metal is entirely free from rust, in which case the ore should exceed this quantity slightly. When all the material is in the furnace, or as much as it will conveniently hold, the current is switched on, and the electrodes lowered until an arc is struck. The current is then kept regulated as near a steady value as possible, and as near to the maximum capacity of the transformer amperage so that the maximum amount of energy is put into the furnace in a minimum time, so that the utmost efficiency can be obtained.

During this period, whilst the metal is being melted, it is almost impossible to cause damage by excessive current energy, as long as the transformers are not unduly overloaded, owing to the proximity of the cold metal which rapidly absorbs heat and prevents excessive temperatures on the lining and walls. Also the arc itself is continually descending into the solid charge, and bores a crater until a pool of liquid metal is produced on the hearth under each electrode. At this stage the slag should be charged into the furnace and distributed around the electrodes and in the craters. A marked change will be noticed now in the smoother operation of electrode control, as the slag has a damping action on the current surges.

The slag consists of a mixture of burnt lime, sand, and fluor-spar—in a furnace of 1 ton capacity 40 lbs. lime, 5 of sand, and 10 of fluor-spar. During the melting period the charge undergoes oxidation from the ore and the phosphorus, carbon, silicon and manganese are carried as oxides into the slag, leaving carbon, silicon and manganese in the bath about 0.08 per cent., and during periods of low temperature of the molten bath the phosphorus rapidly oxidises and is carried into the slag, leaving only 0.015 per cent. on the bath by the time all the metal is melted.

When the temperature has been raised sufficiently to thin the slag, the current is switched off, and the furnace is slightly tilted to pour off the slag, the last traces being removed by raking, and, if necessary, a little dry lime thrown on to the surface of the metal to facilitate the removal of final traces.

The furnace is then restored to its normal position and ferro-silicon is added to the bath to remove the excess oxygen, and in such proportion that the silicon will not remain in the bath. In a 1-ton charge 10 lbs. of 45 per cent. grade will be quite sufficient.

If it is desired to make a steel containing carbon higher than 0.08, carbonising should be carried out at this period by means of anthracite (preferably pea size) allowing 1½ lbs. of anthracite for every 1 lb. of carbon desired in the steel. The anthracite is thrown into the bath, and current is again switched on the furnace, and as the temperature again rises the steel will gradually dissolve the carbon into the bath, the rapidity depending largely upon the freedom from slag in the metal after slagging off. It may be mentioned here that if a high manganese steel is required it will be found unnecessary to carbonise, as the carbon in the FeMn will be often sufficient to bring up the carbon as high as desired, and before doing any

carbonising it should be borne in mind that for every 14 lbs. of FeMn added in the final stages, 1 lb. of carbon will be added to the bath, and allowances for this should be made.

After the anthracite has completely disappeared, a second slag should be charged into the furnace, consisting of 40 lbs. of lime, 8 of sand, 8 of fluor-spar, and after this has become melted a little fine coal dust should be added to reduce any iron oxide in the slag. When this condition is attained a sample of the slag taken on a rod and quenched would appear white, and on exposure to the air rapidly disintegrates into a white powder. A sample of steel taken from the bath and poured into a small sample mould will now indicate the condition of the metal, both as to soundness and temperature. If the metal solidifies without any signs of apparent growths on the surface, this indicates the steel is in a deoxidised state, and any additions of manganese, silicon, or vanadium can now be made without anticipating very much loss by oxidation. If the bath sample is first analysed final adjustment of carbon can be made by adding white iron.

As soon as the additions are all melted, and provided the condition of the bath has remained in its perfectly quiet state, the metal should be ready for pouring as soon as proper temperature is reached. There are various methods in use of gauging the temperature of the steel, all of which methods depend on comparative results, and anyone with a little training can learn to estimate the correct pouring temperature. The best methods in vogue, I think, are the iron-rod method and the sampling spoon. In the first method, an iron rod about $\frac{3}{8}$ in. diameter is plunged into the furnace bath, and held there for 5 or 6 seconds, and the temperature is judged by the amount of rod melted off the end and reduction of diameter of the rod actually in the bath. The second method is by taking a sample of the metal in the sampling spoon, and counting the number of seconds after withdrawing from the furnace until the metal sets solid; care, of course, being taken to use spoons uniform in size, similar quantities of metal, and with surrounding air temperatures and currents as equal as possible.

When pouring the steel from the furnace, it should not be necessary to introduce any aluminium if the metal is taken quickly after showing a sound sample. During the deoxidising period and when the slag is turning white, and is highly basic owing to metallic oxides having been reduced, desulphurisation starts vigorously, and it is only necessary to maintain the condition a few minutes to ensure removal of sulphur to very low contents. Results of 0.012 to 0.015 are quite common, starting with a charge of 0.06 or more. Steel for castings can be produced in a 1-ton furnace for the expenditure of 850 units of electrical energy per ton in the ladle, and in a 3-ton furnace for 780 units, and in larger furnaces less still.

For general casting work the 3-ton size is the practical limit where castings average 300 to 400 lbs.; but where much less castings are required, the 1- to 2-ton size will give better results. In a small foundry a ½-ton furnace can be operated on castings at a very paying rate where electric current is reasonably cheap, and scrap plentiful.

To give an idea of the cost of operation of such a plant, a few figures as follows are given, showing average results obtained on a ½-ton furnace working only two shifts per day, from 7 a.m. to 2 a.m. the following morning. The furnace was thus shut down five hours out of every 24, and week-ends from 12 noon Saturday to 7 a.m. Monday, working only 100 hours for the week. In one week the day shift turned out 23 heats and night shift 20, making 43 for the week, producing 25.35 tons of ingots. The amount of scrap charged was 27.5 tons, the loss being, therefore, for oxidisation and splashes, etc., 2.15 tons, including rust, dirt, etc., on scrap, or a loss of 7.82 per cent.

The average weight of charge was 0.64 tons, or 12 cwts. 3 qrs., the average consumption 957 per ton. This was making steel to specification, refining under two slags and working to close analysis. The time taken from slagging off to teeming was 45-60 minutes, owing to laboratory being slow getting out test sample analysis.

This same furnace, when working only one shift per day over a period of three months, showed a cost of operation of £10 5s. 9d. per ton, excluding scrap, making steel to specification. This cost included all labour in the melting shop and all repairs and moulds; wages, £2 15s.; power at .942d., £4 15s. 3d.; 16 lbs. electrodes at 1s. 6d.; slag materials, 2s.; repairs (time and material), 12s. 6d.; tools, 2s.; mechanical and electrical repairs in the shop, 5s.; moulds, 10s.; making a total of £10 5s. 9d.; or, including cost of scrap, £16 10s. per ton. The steel made was equal in quality to that made in crucibles before the installation of this furnace, when the melting costs were nearly twice those of the electric furnace.

As an example of the quality of tool steels made in the electric furnace, a comparison with a crucible carbon steel of the same composition was recently carried out at the Sheffield University.

The steel made in the electric furnace was produced from old tin cans, which had been de-tinned, and the crucible steel was of average quality. The tests made on the two tools was by the lathe speed increment test on a mild-steel bar, in which the starting speed was 20 ft. per minute, the speed increment 1 ft. per minute per minute, the depth of cut $\frac{1}{8}$ in., and the feed per revolution 1/60 in. Each tool was tested three times. The mean results of the tests were as follows:—

Average duration of test before breakdown: Crucible, 18 minutes 47 seconds; electric, 18 minutes 57 seconds.

Average breakdown speed in ft. per minute: Crucible, 58.8 minutes; electric, 59.2 minutes.

Average volume of metal removed up to breakdown: Crucible, 18.6 cub. in.; electric, 18.8 cub. in.

Although the results of the two steels were very close and show average durability and cutting power of a good plain carbon tool steel, yet when one considers that the material used for the electric furnace was only de-tinned cans, the results obtained could not be achieved by any other process.

The following tensile tests from steel castings, produced in a 3-ton furnace, may be of interest, the remarkable feature being the reduction in area. One test gave 29 tons with 34 per cent. elongation on 3 in. test piece, with a reduction of area of over 50 per cent. High-tensile material gave 42 tons, 25 per cent. elongation; another 45 tons and 20 per cent. elongation; another 50 tons and 16 per cent. elongation. When one takes into account the fact that these bars were simply castings without any work put on them, and that they were every-day results, it is doubtful whether they could be

equalled by any other process without using very expensive material.

The electric furnace as used for steel making has also another sphere of usefulness, and one in the near future will be very much more employed, and that is for making gray-iron castings, where very special quality is required, such as high-pressure and superheated steam engine cylinders, and also internal-combustion engine cylinders.

Strong irons require high pouring temperature on account of high melting points and minimum fluidity, and the electric furnace is the easiest process which can be used to supplement the foundry cupola for superheating. In such a duplex process, metal of the highest quality and low in phosphorus can be produced and poured into intricate castings without flaw. Such castings are stronger, and will withstand shock very much better than ordinary gray iron high in phosphorus; and yet on account of the higher temperatures attainable in the electric furnace, the same degree of fluidity can be obtained as that melted in the cupola alone with a high percentage of phosphorus. The electric process would result in very much lower sulphur content, which would give a higher grade of casting. Also the total carbon can be adjusted quite readily by means of adding varying quantities of steel scrap to the liquid charge as it enters the electric furnace from the cupola.

Carbon regulation in the graphitic or combined form is possible to a most useful extent in the electric furnace, by means of silicon adjustment, and the regularity of the product is such as can hardly be attained by any other process.

An example of the improved results obtained by this duplex method:—An ordinary mixture of pig-iron and foundry scrap melted as usual in the cupola, transferred to an electric furnace and there superheated and refined under a lime slag. The untreated iron was of a composition regularly giving test-bars that broke under an average transverse load of 2,950 lbs. with a deflection of 0.1 in. After treatment in the electric furnace a similar test-bar broke at slightly over 4,400 lbs. with a deflection of 0.115 in. The specific gravity was increased from 7.1 to 7.25. About 25 minutes was the time of the electric furnace treatment, and the current consumption was 104-kw. hours for 2,000 lbs. of iron.

In addition to steel making and producing iron castings, the same furnace can be economically employed for nickel, cupro-nickel, or copper melting, the practice being very similar to that of steel making, except that the killing agents employed vary with the particular class of work. The electric arc furnace of the direct-arc type is quite unsuitable for brass, aluminium or such metals which have low volatilising temperatures.

There is the arc furnace which is regularly engaged in melting brass. (This is the type in which the arc does not come in contact with the metal.) That type of furnace is admitted to be hardly suitable to steel.

Discussion.

THE CHAIRMAN said he had known something of electric furnaces, and he wanted to say candidly that the figures which Mr. Greaves had given he was prepared to endorse. They did seem remarkable, and if the meeting wished to criticise the lecture he was prepared to stand by Mr. Greaves and say that the figures were correct. There was one great feature of the electric furnace, and that was that under certain conditions and operating on certain materials it filled a useful place in the steel-making world; and there were other new furnaces which he was convinced were going to fill a useful sphere in the non-ferrous world. The open-hearth furnace with its intense temperature did not seem to do much harm if carefully handled on steel, but when that temperature was applied to non-ferrous material the losses became too high. He was interested in the handling of tinned scrap. He took it that the scrap would not be rusty, and that would compensate to a very large extent for what they might call an inferior material. He would like to know whether they had tried to melt old scrap without taking the tin off and how the results compared. Of course, they did not like any tin in steel—in fact, twenty years ago they had a distinct prejudice against any tin getting into steel—and he was wondering whether it was a fact that a small amount of tin spoiled steel under the refining influence of the electric furnace. He had found the experiments in cast iron to be very interesting.

MR. BROOKES felt that the electric furnace had not only come to stay but that it was making enormous strides and playing a very important part.

MR. KENT SMITH said he did not pretend to have much personal experience in electric-furnace steel, but he knew the electric furnace in its relation to the production of non-ferrous metals, chiefly scrap. He thought there was a tremendous wall of prejudice to be broken down—prejudice from people who did not realise what principle they should consider. For instance, he heard someone say the other day that the electric furnace was no good because half the steel in his shop was wasted. His reply to that was: "You couldn't have given the electric furnace a better testimonial, because if only half is wasted there is no reason why the lot should not be good." One of the chief advantages of the electric furnace was the wonderful possibilities it had given them of refining in an atmosphere which was almost exactly comparable to that which prevailed in a crucible furnace. People did not realise the difficulties which the atmosphere surrounding steel made to the finished product.

MR. NEEDHAM said that Mr. Greaves' statement that it was impossible to do any harm during the melting down process was not quite correct. There was a great possibility of boring holes in the lining of the furnace, and it was only a careful melter who could prevent it. In regard to melting scrap which had not been de-tinned, his firm had produced quite a good quality of steel from the old biscuit tins, and they found that there was no trace of tin in the product. Furthermore, they took no special precaution. At the same place they made steel from scrap parts of sewing machines and bicycle frames, which was a testimonial to the fact that the electric furnace would make good steel from almost anything.

MR. DALTON said that he was surprised about the prejudice which the electric furnace had encountered. He gained his first experience of the electric furnace not in this country, and he had come back to England to help his firm along with their furnace plant. He could not agree with Mr. Greaves that anyone with a few weeks' tuition could make steel with the electric furnace. There was steel—and steel. The ingots might look

pretty—they might be more or less sound; but if he were situated next door to a steel hospital he might get some of his steel back again. When comparisons were made one had to be very careful. The best testimonial was reliability in tool steel, and that was what made the repeat orders come along. To this end great attention had to be paid to temperatures and non-metallic inclusion. He did not think that the mere fact of inventing the electric furnace was going to solve the problem. It was no good unless they had some skill in their operatives. At the same time, he was quite convinced that electric steel was not only equal to crucible steel, but he was getting more and more convinced that it was superior to crucible steel—made under careful conditions. He had to admit that Mr. Greaves was right in one remark of his. He had seen shell steel made satisfactorily by the lowest class of Italian labour, though it was not done in Mr. Greaves' type of furnace. It was in a single-phase furnace, and it was a very ordinary steel, certainly. His point was that, when it came to a superior steel it needed superior people to handle and get the best out of the furnace. He went on to deal with the difficulties presented by white slag and the "wildness" of steel. He had found this to occur in electric furnaces on acount of the absorption of gases and the high temperatures. Certain gases came off, and no amount of white slag would make the steel less wild in spite of it being a low-carbon steel. In regard to Mr. Greaves' remarks about non-ferrous furnaces, to the effect that the direct arc was not suitable for brass, he believed the Americans were running a radiated-arc furnace in which, it was claimed, very successful results and a minimum loss in zinc were secured.

Mr. Wilkinson asked the lecturer whether it was necessary to get the high tensile strength which was obtained in the electric furnace when other cheaper furnaces produced the required results. The lecturer had also mentioned the refined process in connection with cast iron, and he (Mr. Wilkinson) believed it was under consideration in some foundries to put down electric furnaces to melt cast iron. It would be interesting to get the comparison between the working of the electric furnace and the ordinary practice in cast iron. At the moment, in the ordinary practice, they were faced with the increased cost of coke and half-a-dozen other things which would make the comparison with the electric furnace very interesting. Coal was most difficult to get, and it was practically impossible to get suitable coke at the present time.

Mr. Greaves, in reply to Mr. Harrison in regard to the tin and its effect in the steel, said he was not sufficient of a metallurgist to be able to answer that point; but when his firm approached their friends to undertake the melting of the tin scrap, they were very anxious to learn what was the residue per ton left from the scrap, as they were afraid that the effect would be very serious upon the steel that they made subsequently. An analysis was required to persuade their friends that the amount of tin was very small indeed. It turned out to be 0.15 per cent. Steel produced from that scrap did not even show traces of tin. Mr. Needham had referred to his statement about damage to furnaces—the putting of excessive power into the furnace at the time of melting. What he said was that one could not damage the furnace by putting excess power into it. He thought that Mr. Needham would agree with him that putting even a minimum of power into the furnace under certain conditions would damage the lining, and, of course, a man who worked the furnace in that state of things did not know what he was doing. He ought to guard against it. Whether he used a minimum of power or a maximum of power he still thought there would be no damage to the furnace lining. Mr. Dalton had also challenged his statement about unskilled labour on the electric furnace. He quite agreed with Mr. Dalton regarding unskilled men in reference to high-quality steels. He meant his remark particularly to refer to casting work where high-class steel was not called for; and he did know places where men were operating furnaces on casting who had never had experience before and yet their results were as good and better than those produced in processes used under the control of expert men. Even an unskilled man who had never seen steel before, provided he had common sense, could easily be taught. There was nothing really abstruse in steel making. It was a question of using common sense, probably in a degree higher than it was ordinarily called for. An intelligent man could do the operation. They had only had electric furnaces in the country for the last ten years, and they had to start with unskilled men. They had produced an excellent type of man after a certain period of training. That period of training had not been anything like so long as the period of training in other processes, and yet in ten years of electric-steel training they had deve'oped a skill almost equal to the skill developed in the steel making of other processes which had been going on for an infinitely longer period. He thought the argument was all in favour of the process which was capable of turning out satisfactory steel under the hands of unskilled men who had had a shorter period of tuition.

Mr. Greaves, proceeding, said that Mr. Wilkinson had asked about making iron castings from electric furnaces. The cost of operation in a two-ton furnace would be something in the neighbourhood of £6 5s. per ton of iron introduced, taking the power at 8d. per unit. He did not know how that would compare with cupolas. It would not be a feasible proposition to melt pig-iron entirely. Those who had tried to melt down pig-iron in an electric furnace had found what a difficult thing it was. The pig-iron was so loaded with sand that one got very bad contacts. He had wasted an hour trying to do it, and he had had to put some scrap iron in before he could get going. He did not think the time had yet come when pig-iron alone would be melted for casting work, the cost being so high in regard to electric power.

Reference had also been made to castings which were already strong enough for what they had to do. If one made a casting about six times as large as was needed one would certainly get strength. If one had a uniformly sound, high-quality steel and put a small casting in, in the place of the large mass, it was economical. The time was coming when they would have to look around and cut down the amount of steel in making machinery. English manufacturers had been in the habit of putting far too much steel in every machine produced. In America, Belgium, Italy, France and Germany their object had been to cut down the quantity of steel and by so doing cut down the cost of production—no matter whether it was motor-cars or machine tools.

XUM

Institution of British Foundrymen.

BIRMINGHAM BRANCH.

Core Stoves and Mould Drying.

At a meeting of this Branch recently Mr. J. Robinson (Halifax) read a paper on—"Core Stoves and Mould Drying," Mr. H. L. Reason occupied the chair.

MR. ROBINSON said the paper originated from his experience of considerable difficulty in getting a good core stove. They were under the necessity of rebuilding their foundry and they took the opportunity to make the necessary changes to the core drying arrangements. He thought good results could be got from the use of a fan blowing into the core stove. They would then have a clean arrangement, doing away with a lot of the fumes which were unavoidable with a direct fire using the old-fashioned stove. At the same time he was afraid at the present time it was not exactly a commercial proposition. Success or failure in the drying of cores depended (1) on the temperature attained; (2) on the rate of heating; (3) on the length of time the heat was continued; and (4) on the construction of the core. During heating hygrocopic moisture was expelled. This might be followed by the expulsion of moisture and the subsequent charring of organic matter (straw, dung, flour, and similar matter in the shape of binders) in the core or moulding sand, and by the expulsion of water in the clayey matter in the core. Loss of moisture should tend to produce contraction, but this was not more than counteracted by the heat expansion of the sand grains and iron supports of the cores, so that the external dimensions of a carefully-dried core slightly increased while drying. This was due to the material of the core becoming rigid and set while hot and expanded. On cooling, the new positions into which the sand grains had been forced prevented contracting to the same extent, and it became permanently enlarged. It followed that the temperature of the drying stove which would determine the rate of heating, and the final temperature would determine the expansion thus taking place.

With large cores only the outer layers and more accessible parts would be heated to the full temperature of the stove unless left in for a long period. Rapid heating and high temperature had a tendency on ordinary sand to increase the surface porosity which did not extend to the back layers unless similarly heated. The effect was important, as it meant that it was easier for the gas and air in that portion to escape into the mould and into the vent provided for its removal. If a core which had been rapidly dried were broken across there would be no difficulty in appreciating the difference in the density from different layers. High temperatures also caused decomposition of the organic substances in the core. Oil began to char at 550 deg. Fah., and starch and core gum at 470 deg. Fah. It was obvious that where these were used the temperature should not exceed these figures. Other organic matters behaved in much the same way and straw could be burnt out at 600 deg. Fah.

It therefore followed that cores could be best dried at a comparatively low temperature, the heat being continued until the drying was complete. Dry sand and core sand containing clay wash or loam and sharp sand would withstand a hotter fire and more rapid drying than those mired with gum starch or much moulding sand. Sand containing much clayey matter was somewhat liable to crack if dried too rapidly, but the trouble was even worse with sand containing gum. Evenly heating the surface tended to prevent this.

Turning next to the question of moisture, the author said that in ordinary cores and dry-sand work they had about 12½ per cent. of moisture, and to get rid of this it was necessary to place the moulds or cores in some heated confined space, or use some other method. In order to dry any material in a confined space, it was necessary not only to heat the air, but to change it before it became saturated with moisture; otherwise the material was simply steamed, not dried. John Sharp, in his book—"Modern Foundry Practice," stated that experiments had proved that by having a brisk current of air 36 grains of water per minute could be carried off from the same surface that only gave off about 22 grains of water in a still atmosphere. It would appear, therefore, that a high temperature with a brisk current combined the most favourable conditions for drying, but with regard to cores and moulds the limit of both these conditions was soon reached, therefore not only the temperature but the current of heated air required to be regulated to suit the core when dried, so as to produce the best results; in other words they had to regulate the flow so as to maintain an atmosphere in the interior of the drying stoves sufficiently below the point of saturation with water vapour, avoiding at the same time an excessive draught or tearing current of air.

The weight of water held in suspension by still air increased rapidly with the increase of temperature. Thus with the barometer at 30 in. and the temperature at 32 deg. Fah., one cubic foot of air was saturated with 2.3 grains of water. At 100 deg. Fah., the saturation would be 19 grains; at 150 deg. Fah., 70.5 grains; whilst at 200 deg. Fah., it would hold 204 grains. But to remove this vapour from the stove a current of dry air must be kept constantly passing through the heat.

The amount of fuel which was generally consumed by the ordinary process of drying cores and moulds was far in excess of the theoretical requirements. This arose partly from defective construction of the stove and partly from inefficient firing, while there was want of control over the ingress and egress of air. The work to be done was usually very small in comparison with the weight of coal or coke consumed. A slow current of warm air 450 deg. to 500 deg. Fah., had to be kept constantly passing through the stove and carrying off the vapour from the wet moulds. Assuming that 1 lb. of coal would evaporate 15 lb. of water at the pressure of the atmosphere and that one cubic foot of wet loam contained about 30 lbs. of water, then 2lbs. of coal should be sufficient to effect the drying of one cubic foot of wet loam. To take an actual example, there were three stoves 13 ft. 6 in. by 12 ft. by 8ft., giving a total capacity of 4,131 cubic feet. This would work out at approximately 23 tons of cores, and in the experiment actually 20 tons of cores were dried. In 20 tons of cores they would have, on the basis of 12½ per cent. moisture, 2½ tons of moisture, which, on the assumption that 1 lb. of fuel would evaporate 15 lbs. of water, 375 lbs. of fuel would be sufficient to effect the

drying of 20 tons of cores. But such a result had probably never been attained, certainly not by the old-fashioned mode of firing. Actually, in the case in point, 12 cwts. of coke were used, giving the moisture evaporation or a little over 4 lbs. per lb. of fuel.

Gas firing in foundry practice was in many instances replacing the older methods of direct combustion of fuel, because that form of combustion was practically perfect, and therefore the dried moulds, etc., were free from the usual smoke or dirt associated with direct combustion of coal burnt in an open grate. With gas firing the amount of air and gas for combustion was entirely under control, so that altogether there was much less waste of heat and the cores or moulds, after drying, were free from the usual coating of soot.

Whether coal or coke was used for the production of gaseous fuel there was practically no difference so far as the drying properties were concerned, and in each case the gas was CO. Various arrangements for the proper combustion of the gaseous fuel had been adopted, each of which was more or less efficient, according to the nature of the work to be done.

Broadly stated, the process in which they were at present interested was the heating the air, in order that it might absorb or hold in suspension a greater amount of vapour. The vapour was abstracted by the hot air from the various damp moulds and cores in its passage through the so-called drying stove.

The lecturer proceeded to exhibit a series of slides illustrating various descriptions of drying stoves. He remarked that the old-fashioned method of direct firing was extremely wasteful and unsatisfactory, although an old foundryman might not believe that.

In the first stove illustrated by the operator, the hot air passed into the stove along each side of the combustion chamber, passing round the stove. It worked with natural draught, which was naturally subject to weather variations, the dampness of the atmosphere and the direction of the wind. The owner of that stove considered it a fairly effective apparatus, but he (the author) had not seen it at work.

In another installation put down in accordance with the patent of H. M. Lane, of America, the air was introduced by a fan. All the air going in for combustion passed through the fire hole door and underneath the fire bars. There was a fan blowing air down a couple of pipes. The air passed along the side of the stove, and the heat would pass through the fire box. The rest of the arrangements followed the ordinary lines of stoves. This particular stove had a fire box 5 ft. by 4 ft. and burned 9 cwt. of coke in 12 hours, which worked out the fuel consumption at 6.6 lbs. of fuel per cubic yard of core stove space. In another stove they consumed 12 cwt. of coke in 24 hours, which gave 8.8 lbs. per cubic yard of core stove space. The moisture evaporated was equivalent to just over 4 lbs. of moisture to 1lb. of fuel, and in another case they used 9 cwt. of coke to dry 20 tons of cores in 24 hours.

Another installation was operated on similar lines; the air passed round the brick work taking up heat on the way. They certainly got a much cleaner method of firing if they had a moving column of air. In the arrangement described they got the air away after it had done its work. In another form of stove the fuel was turned into gas before it was used for combustion. Undoubtedly the comparison between the direct-fuel firing and gas firing must tell heavily against direct firing. In the particular example there was an arrangement to maintain a certain depth of fuel and the air passed into the fuel from the bottom and was then turned into gas, and was passed into the combustion chamber. When the gases had done their work they were passed round retorts and found their way out again through square boxes. As they went back to the flue they utilised all their heat. The combustion took place in the heating chamber. A further view showed a core stove with a gas fire, manufactured by Messrs. Muir Murray & Company. The fuel used was ordinary gas-works coke. Combustion took place in the first instance at the grates in the bottom of the producer and the products of this combustion (CO_2) passed up through the fuel in the producer, picking up carbon from the fuel, and were thereby converted back to carbon monoxide (CO). This gas passed through ports at the top of the producer into the combustion chamber in the combustion stove, where it met with a supply of secondary air which had been preheated at about 900 deg. Fah., and this union gave complete combustion and the products passed through a series of ports evenly distributed over the width of the stove, then through the stove and into the waste-gas flue leading to the chimney at the opposite end. There were two ash pans at the bottom of the producer which were kept filled with water and the hot ashes dropping through the grates generated a small supply of steam which served the double purpose of improving the quality of the gas and preventing the formation of excessive clinker in the producer.

The firm explained that the producers for mould drying were usually worked on natural draught, but if higher temperatures were desired such as for heating shipyard furnaces, blowers were used with a steam pressure of 30 to 40 lbs. per sq. in. The producers, when charged up at, say, 5 p.m., would run until next morning without further fuel or attention, and as the heats were much more uniform than with direct firing there was no cracking or burning of moulds. There was no smoke or smell with the system, and the moulds, when withdrawn from the stove, were free from soot. The producer only required cleaning every 24 or 48 hours. The stoves were usually fitted with asbestos panelled lifting doors and sealed at the top, which were much more durable than the common form of iron or roller door, and, in addition to conserving the heat in the stoves, were always easily handled and they did not warp under heat. The firm went on to say that they recently converted and enlarged two stoves which were fired with open coke furnaces at the back of the stoves, with the following result.

In the old system the area of the stoves was 160 cubic yards. The consumption of fuel 17 cwts. per 24 hours, representing 6 tons per week at 34s. 6d. per ton and cost £10 7s. The attendance at the rate of five minutes per hour would equal 14 hours per week, which at 1s. 5¼d. per hour would total £1 0s. 1½d. This worked out at a cost per cubic yard per week at 1s. 5d. Under the new system the area of enlarged stoves was 323 cubic yards. The consumption at the rate of 18 cwts. per 24 hours was equal to 6 tons 6 cwts. per week, but reckoning the cost at 34s. 6d. this

gave a fuel cost of £10 17s. 4d. In that case the attendance was 2½ hours per day, or 17½ hours per week, at 1s. 5¼d. per hour, costing in all £1 5s. 2d. The cost per cubic yard per week was 9d. as compared with 1s. 5d. under the old system.

The next stove was the manufacture of Messrs. Hislop. This was a class of stove which he (Mr. Robinson) had employed in his own factory and he considered the results obtained were particularly good. It was possible to attach either one or two stoves to the generator. There were rolled steel joists passing along the top of the stove and there was an abestos covering which made an excellent top for the core stove. That stove had been in operation for 14 years and had not yet developed any weakness.

A further view showed a stove with asbestos doors substituted for iron panels, the object being to prevent the radiation of heat, which was a matter of importance. Another view exhibited Kinnear steel rolling shutters as applied to core-drying stoves.

A headroom of about 14 in. to 18 in. was sufficient for shutters of ordinary size. They required no floor space kept clear, and interfered in no way with the foundry floor whether open or shut. They did not buckle and were easily and rapidly operated. Continuing, the operator said, one undoubted advantage of the gas heater as against the direct fire was that the air supply could be regulated. With the direct fire it was necessary to admit more air than was really needed and thereby was got an excess of nitrogen, which was not a combustible gas.

Discussion.

THE CHAIRMAN, referring to the necessity of keeping a current of air going through the stove, related how he had found the core stoves working very indifferently, and had known cases where the heat had been so great as to melt the mould boxes. They sometimes used core ovens for keeping crucibles dry, and no doubt the moisture in core ovens not properly ventilated was likely to have disastrous effects on crucibles placed in the oven.

MR. HOLBERRY said he was surprised to see how very low was the consumption of fuel in some of the stoves that had been exhibited.

MR. FIELD said that the class of work he had to do with called for cores weighing from half a pound to a pound, and he thought that the stoves exhibited would hardly apply to that kind of thing. He believed that the general practice in that district, unfortunately, was for the bulk of the cores to be dried by direct fires, and it was very clear what an amount of time was lost and how great was the waste of fuel with that method of drying.

MR. PEMBERTON said the most interesting point to his (the speaker's) mind was the necessity for the circulation of air in the core stove, and he had seen that very completely demonstrated in the chemical laboratory. Quite 90 per cent. of the core stoves in the country, certainly of the old foundries, were started many years ago, and unfortunately were direct fired. The problem confronting the foundryman was the conversion of the old stove into the new stove. The cost was a very serious matter. If it was a question of building a new factory there ought not to be any doubt as to the wisdom of putting in a proper modern stove. He would like to know what would be the saving in fuel by substituting a Hislop drying stove, gas fired, for a stove 12 ft. by 10 ft. with a height of 7 ft.

MR. GAUNT pointed out that the stoves to which the author had been referring were mostly suited to large foundries. But in that district there were hundreds of foundries casting small articles, and therefore requiring very small stoves. No reference had been made to stoves heated with town gas. It was often very economical and desirable to have the stove in the shop where the men were at work, and in his (the speaker's) experience they were usually gas fired. He would like to know also whether Mr. Robinson would recommend any of the stoves he had referred to for that class of work where they were using town gas.

MR. J. G. DOBSON considered, despite all that had been said, they could not get very far ahead of the old-fashioned stoves having their flues at the bottom near the floor. By that means they got the stoves full of heat, driving out the cold air and moisture, and getting the moulds and cores dry within a reasonable time. Taking into consideration the extra cost of construction for putting in those new appliances he was not prepared to change from the old method. In his experience also it did not involve any difficulty in the way of maintaining heat through the night, which could be easily done by the man in charge.

MR. ROBINSON, replying to the discussion, said Mr. Pemberton had raised the question of the cost of turning over from one class of stove to the other. It was quite true there was a fairly large outlay, but when they had the certainty of a saving every day the first cost ought not even to be considered. It was obvious that they would be fully repaid by the daily saving. Apart from the cost of fuel, there was such a tremendous difference in the saving of labour, not only in the bringing in of coal, but in the carting away of ashes. Then the question of the difference between direct firing and gas firing was very important from the point of view of foundry labour. It was not altogether a wages question. They ought also to take account of the great difference which would be made in the shops if they had modern stoves, in respect of the amount of fumes given off. All that had to be considered when they were comparing the difference between direct-fired and gas-heated stoves. He was afraid that cost-taking was a matter unfortunately neglected, and unfortunately very few people really knew the amount of fuel they were using.

With regard to their past experience with the stoves he could give them some particulars. They had three Hislop stoves, 32 ft. long by 10 ft. 6 in. by 9 ft. high, and they had one stove 32 ft. by 18 ft. by 9 ft. high. The total capacity was 14,400 cubic feet, and the fuel consumption 27¼ cwt. per day, which worked out at 5.8 lbs. per cubic yard for 24 hours. That represented the coke used taken over a 12 months' run. That consumption worked out at 7.35 lbs. of moisture evaporated per pound of fuel, per cubic yard of core space for 24 hours. One-eighth of the capacity of the store was filled with cores or moulds. The gentlemen who wanted to have comparative figures would be able to compare those figures with their own in connection with the old-fashioned stoves.

With regard to town gas he had had no experience at all, but there was no doubt town gas could be very satisfactorily burnt, although whether it would be profitable at present prices would, he

should think, be very questionable. If he wanted to use a small stove he would use the Portway stove, which was the best he knew of that description. Very little fuel was burnt, and small cores could be dried very quickly with a small amount of gas.

As to night firing, a certain amount of night firing was necessary. The great point to insist upon with regard to getting rid of moisture was that they must have a moving column of air to absorb it. During the war his firm produced a lot of cast-iron shells, and the biggest trouble they had was to get them turned out clean on the outside. It was rather a big job to put all those moulds into a stove. But he built a channel covered with cast-iron plates, and he blew air through the heating chamber, and it worked quite satisfactorily. It was quite possible to dry his cylinders satisfactorily. He was quite convinced that a great deal of the waste involved through bad work resulted from not thoroughly drying their sand work. He did not believe in hurried drying for cylinder work, and very often he refused to accept a time limit.

COVENTRY BRANCH.

Annual Meeting.

The annual general meeting of the Coventry Branch was held on April 16, the Branch President (Mr. Andrew Harley) in the chair.

The SECRETARY in his report said that they could congratulate themselves on a very successful beginning. "Starting from a nucleus of 23 members of the Birmingham Branch, we have now a membership of 275, including 32 full Members, 150 Associate Members, and 93 Associates."

The BRANCH PRESIDENT nominated Mr. F. H. Hurren as his successor for the ensuing year. This was seconded and approved. Messrs. E. Cary Hill and G. E. Roberts were elected Senior and Junior Vice-Presidents respectively, and Mr. F. H. N. Lane was re-elected Secretary. Mr. G. Rollaston was re-elected Treasurer, and Messrs. E. Carey Hill, G. E. Roberts, and A. Harley were appointed delegates to the General Council. Messrs. Williams, Glover, and Ashmore were elected to fill three vacancies on the Branch Council, one of which was due to the retirement of Mr. E. H. Broughall and another by that of Mr. Orbridge.

MR. F. H. HURREN, in proposing a vote of thanks to the retiring President, Mr. Harley, commented on his valuable work, especially in connection with the inauguration of the Branch.

MR. HARLEY, in responding, said he believed Coventry was the largest Branch of the Institution and he hoped it would retain that position.

It was decided that Wednesday for next session would be a more suitable evening, the time for commencing being fixed at 7.45 p.m. The meeting concluded with a smoking concert.

NEWCASTLE BRANCH.

Visit to the American Foundrymen's Convention.

By R. O. PATTERSON.

At a meeting on April 24, in the course of a description of a visit to the Annual Convention and Exhibition of the American Foundrymen's Association, held at Philadelphia during the week commencing September 29, 1919, the author said:—Of all the exhibits, Moulding Machines were the most interesting. The jar-ram machines were predominant, both pneumatic and electrically-driven, and were in great variety. These machines have been brought to a wonderful state of perfection and the variety of work that can be done on them was away ahead of anything I expected. The vibrators which are almost universally fitted have made it possible to operate on machines the most intricate patterns without the use of a draw-plate. Of course, the patterns were perfectly made, no expense being thought too great if any improvement was gained. The jar, turnover, draw machines are now up to 15 tons capacity, and are most efficient. I am certain that their installation would pay any founder whether he has repetition work or not.

Great labour savers are the gyratory riddles. These are driven by small electric motors about ½-h.p. and can pass sand through as fast as a man can shovel it in.

Another interesting machine was the electrically-driven sand cutter. This machine is guided along the shop floor and cuts the heap sand in much the same way as the farmer's machine turns the hay in the field. It can be steered all over the shop floor and leaves the sand in a neat heap and in a very well aerated and tempered condition.

Amongst the pneumatic appliances was a small hinged core bench supported by a spring at the front. When the core was finished, the operator, before stripping, pressed down on the bench and this set to work a vibrator under the bench plate and saved the operator the trouble of rapping the core-box.

Steel moulding boxes were exhibited in great variety and these are undoubtedly a great advance on the ordinary cast-iron boxes used in this country. They are very light and rigid and the section is made so that the sand has a good hold and will not easily slip out.

The sand-blast cleaning plants exhibited were very interesting. They make an excellent job of the casting, but I think that when the cost of charging the machines is added to the running costs, dressing by hand will come out cheaper.

Lifting tackle for the foundry was well represented. Several electric crane makers were there but electric pulley blocks were predominant. These, I found afterwards, when visiting the foundries, are very largely used, and have almost entirely superseded the pneumatic cylinders which were so common a few years ago. These blocks suspended from a runway are very handy and well worth consideration.

After the Convention the writer visited various towns and foundries and here wishes to say how much he appreciated the unfailing courtesy with which he was received.

In Cleveland I saw an example of a typical mechanical foundry. They were making back axle housings for motor trucks. A green-sand core was jar-rammed on one machine, whilst the mould was being rammed on another. The bottom half core-box was lifted off and the drag mould lowered into the other half core-box, cramped together, the lot turned over, lowered into the conveyor and the top half core-box lifted off. The cope which was rammed on another machine was then slewed around and lowered into position and cramped up. The conveyor was set in motion and carried the mould clear from the machine into casting position. The

metal came along an overhead runway, and the job cast. The top half was lifted off, lowered on to a jar machine, which shook out the sand. The casting was lifted out and put into another jar machine which was rigged up with a jig to hold the casting in position while the core was shaken out. The casting was then run away to a cleaning room. The drag mould was shaken out on the first shaker machine. All the sand fell through a floor grating on to a conveyor, taken away to the sand mixing room, and returned after treatment by an overhead conveyor, which delivered the sand into hoppers at the various moulding machines. This may appear to involve an extravagant capital outlay, but when one considers that four men are making eighty to ninety complete moulds per day, of a most intricate casting, it is worth consideration. The complete mould measured 4 ft. 0 in. by 2 ft. 6in. by 2ft. 0 in. deep.

The sand handling plants which I saw installed in several foundries were a revelation to me. The idea roughly is to collect the sand where the moulds are shaken out, convey it to a sand treating plant in a separate room, and deliver it back right at the moulding machine. The whole operation is more or less automatic, three or four men handling about 100 tons of sand per day. I saw plants of about this capacity which cost approximately £6,000 to £7,000.

At the International Harvester Company's Works at Chicago, there were installed 30 to 40 moulding machines. The sand was fed down a shaking chute on to a vane fixed on end of a rapidly revolving spindle running horizontally at about 1,400 r.p.m. This vane caught the sand and threw it with sufficient force down on to the pattern below to ram the mould. Thus obviating the filling in of the mould by shovel. A large variety of castings were being made on these machines but nothing above about 1 cwt., although to the touch the moulds are quite firm and suitable for heavier castings.

Another plant I saw which was for the manufracture of 4-in. soil pipes. There was an entire foundry laid out for this one pattern alone, and the total cost of the plant which had just got under way, was something over £7,000. This figure was for box-parts, patterns, moulding machines, cranes, etc. The pipes were 5 ft. long, 3-16 in. thick and made four in a box. They were jar-rammed, the boxes being handled from the machines to the floor by overhead crane. The cores were greensand and made by sand falling in a guide for 6 ft. on to the clay-washed core bar. A knife-edged strickle board was set to determine the diameter of the core. This was the most rapid method of making pipe cores I have ever seen, a core being completed in one minute.

I have come to the conclusion that the foundry engineer is a man that has to be considered in the future in this country.

I think the Americans have been forced into their present methods of operation by the lack and price of skilled labour. They must have their patterns perfect and their mould machines more or less automatic and fool proof because they must take the "green" labour direct from the emigrant ships. These men from Poland and such like countries are taken straight into the shops and put to work on time on a certain machine. The machine is so perfectly got up that in about two weeks' time, the men are working on piece work and getting a very big output.

I cannot say too much about the perfection of their moulding plant. There has to be absolutely no mending up of moulds, if there is, the men are not skilled enough to do it and therefore the machine is of no use to them and has to be scrapped and something better installed. All sorts of devices are used to prevent wasters, one of which struck me as being decidedly good. That was, a strainer core was put down at the bottom of the gate to strain the iron and keep back any dirt which might be in the metal.

Steel box-parts are greatly used. The pins fit and they are perfectly rigid, and undoubtedly are a great factor towards producing perfect moulds. I found that oil-sand cores were almost universally used. The drawback to them I think is that, unless they have a flat surface, a shaped casting has to be made to hold each core to its shape until same is dry. In spite of this difficulty there are decided advantages to be gained by the use of these cores, in the rapidity of output, little or no core irons required, and in the facility with which the cores are got out of the casting. I was strongly advised by nearly everyone, that if I meant to go in for oil cores, to go in for linseed oil, or some core compound with a linseed oil basis in preference to those with a molasses basis. The linseed oil is more expensive but the results justify its use.

In Chicago I visited one of the biggest malleable-iron casting plants in the United States. Here they were using exclusively powdered coal for fuel, both for melting and annealing. This fuel seems to have great possibilities. The coal is powdered in a central crushing plant, and conveyed all over the works to the various furnaces through pipes. It appears that a very small jet of "dry" compressed air introduced into the pipe is sufficient to make the coal dust travel through the pipes.

There is a hopper at each furnace which is kept full, and the coal dust is fed by a screw (the speed of which is controlled) into a sort of Bunsen burner and blown into the furnace by compressed air. It burns like gas and a very intense heat is obtained. The whole installation is very clean, handy and economical. The coal is powdered so finely that all or nearly all the clinker goes up the chimney, and a very low grade coal can be used with very satisfactory results.

With regard to jobbing work, I saw very little of it, but what I did see compared very unfavourably with what we turn out here, especially the cheaper class of castings such as man-hole covers and the like. In this line they do not attempt to finish the mould, as long as the casting does the job, it is good enough.

The lesson to be learned from such a visit is, how to spend money. These people do not seem to consider the cost of their tackle. They must have it perfect and worked with a minimum of labour, and to obtain that end no price is excessive. At the same time, their market seems to be different to ours inasmuch they seem to be able to run one pattern more or less indefinitely and always get a sale for the article.

It has been decided to form an association to be styled the Birmingham and District Association of Stamped and Pressed Metal Ware Manufacturers, and to put forward a claim for adequate representation on the Stamped and Pressed Metal Wares Trade Board.

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NOTES AND COMMENTS.

Scientific Research for the Foundry Industry.

There is at last every possibility that the ironfounding industry will be given an opportunity to reap the benefits that must accrue from the efficient application of scientific methods. Steps are being taken by the Council of the Institution of British Foundrymen to form a Research Association, under the auspices of the Department of Scientific and Industrial Research. As the result of the various conferences which have been held in Birmingham, Sheffield, and elsewhere, definite steps have now been taken to form a Research Association for the Grey and Malleable Cast Iron Trades, under the auspices of the Government Department of Scientific and Industrial Research. The trade has been circularised and a very encouraging reception has been given to the scheme. A census has been taken of the trade, and from this it appears that there are about 2,800 foundries in the United Kingdom, 285 being in Scotland, and 50 in Ireland. Yorkshire has the largest number of any county, namely, 415. The industry, however, is concentrated more markedly in the Midland area, in which there are 828 foundries, whilst Birmingham, with a total of 118, has more foundries than has any other town.

It was, therefore, felt that Birmingham was naturally designated as the headquarters of the new Association. It has also been selected as the centre for the Non-Ferrous Metals Research Association, and there are in the city two or three important research laboratories, whilst the Birmingham University, with the Metallurgical Department under the direction of Professor T. Turner, and the Municipal Technical School, will be able to co-operate with the Research Association

The objects of the Association will be to arrange for the carrying out of scientific and industrial research, and the dissemination amongst its members of technical and other information relating to the production, treatment, processes, and methods of manufacture, and uses of cast-iron and general foundry practice. These will be attained by setting up a Bureau of Information wherein technical details of value to the trade will be collected from every part of the world, and further by laboratory research work.

The research work will include every part of foundry work, including the suitability of pig-irons, sands, loam, refractories, heat treatment, chilling, pattern-plate making, machine moulding, etc.

As the industry stands to-day it is further advanced in the United States owing to their progressive research work, and there is no doubt that if the foundry industry in this country does not take the necessary steps to bring its foundries into a more advanced condition, it will have a most serious effect upon the engineering industry. The relation of the foundry to manufacturing enterprise is indeed a manifold one; for instance, there is practically no branch of engineering, using the term in its widest sense, in which malleable cast-iron cannot be used to advantage.

Possibly no industry in this country will therefore benefit more from research work than the ironfounding trade. In the past it has occupied anything but a creditable position among the manufacturing industries of the country; very little progress has been made from a scientific point of view, archaic constructions and antiquated methods are tolerated complacently by employers, and in consequence there is a tremendous amount of leeway to be made good before the foundry can be raised to its proper position amongst the other leading industries of the country which its importance warrants.

And to this end the new Research Association will devote all its power and organisation. It will invite all British firms who are engaged in any branch of the foundry industry to join the Association, and thus

to become eligible for benefits resulting from the scientific investigations it will carry out. The scheme of research will cover the whole field of operations from the production of pig-iron to the complete finished goods. It is obvious, therefore, that every ironfounder must recognise the urgent necessity of his joining the research scheme if he intends to maintain his position in the industrial world, and in so far as he fails to do so, the more progressive manufacturer, whether he be in this country or in some foreign country, will assuredly reap the benefit.

It is proposed to have the offices and laboratory at Birmingham, owing to its central position. A meeting of the trade will be called there in July to inaugurate the Association.

The practice of the Government in regard to the formation of such associations is to contribute a sum equal to the contributions of the members. Appeals will be made to all firms interested in foundry work to join the Association and to provide funds. The personnel of the new Association cannot at present be announced. A number of gentlemen, eminent in the foundry and engineering world, have interested themselves in the matter, and it is hoped that a gentleman of world-wide fame in the industry will be the first President. The organisation of the Association has been entrusted to Mr. T. Vickers, who, in addition to his qualifications on the metallurgical side, has given evidence of his ability as an organiser in the remarkable growth of the Birmingham Metallurgical Society during his secretaryship.

Large Ingot Mould Casting.

An ingot mould of large dimensions and weight and the pouring of which involved some difficult problems in moulding and pouring, particularly as regards the core, was recently made by the Buffalo Foundry & Machine Company, Buffalo, N.Y., for the Pittsburgh Crucible Steel Company, Pittsburgh. The finished casting weighed 114 tons and was 17 ft. 2 in. long. The following account of the production of this casting is furnished by the company.

In order that a thoroughly sound casting might be obtained, it was poured on end. To accomplish this the mould in which the casting was made was erected in a moulding pit extending 14 ft. below the floor level. Due to the fact that water is reached at 8 ft. below the floor line, it was necessary to make this moulding pit absolutely water-tight.

In pouring castings of this character on end it is customary to cast large risers on the casting so as to provide a quantity of metal upon which the casting itself draws. An experienced foundryman will appreciate the difficulties encountered in pouring on end a casting of this weight and character.

One of the important requirements was that the diameters of the mould should be the same at both ends. Owing to the height of the casting and the consequent high head of liquid metal, it can be readily seen that the pressure at the bottom of the mould would be a serious factor in pouring this casting; in fact, the pressure at the bottom would be so great that there would be a tendency to crush the core and force the walls of the mould inward, thereby reducing the diameter of the casting at this point. One of the problems, therefore, was to construct the core so that it would be sufficiently strong to withstand this crushing tendency and, at the same time, be sufficiently pliant so that it would yield to the shrinking process which takes place as the casting cools. It should also be sufficiently porous to allow the escape of the gases that are generated in the core through contact with the heat of the molten metal. As the rate of shinkage in the diameters at the bottom of the mould would be different from that at the top, it was, of course, necessary to regulate the diameters of the core and mould at the top and bottom to such a degree of nicety that when completely cooled and all shrinkage had ceased, the resultant diameters would be alike at both ends of the casting.

As already mentioned, the finished casting was approximately 114 tons, but to pour it there was provided a total quantity of 135 tons, the excess representing gates, runners, and the riser which was cast on the mould as mentioned. In order to have this large quantity of metal ready for pouring at one time, it was necessary to make special provision for storing a large portion of it. This was done by building adjacent to the mould a reservoir with a capacity of 70 tons. This reservoir was made up of cast-iron rings and properly lined with fire brick and clay to hold the molten metal. In addition there were three ladles of molten metal holding respectively 25, 30, and 10 tons. The 70-ton reservoir was connected to the mould by means of a trough, and at the proper moment the plug at the bottom of the reservoir was withdrawn and the molten metal released and conveyed to the mould through the trough. At the same time the ladles were poured into the mould through other similar runners.

Some idea of the crane capacity required for handling castings of this kind can be obtained when it is considered that in addition to the casting, which in itself weighed 135 tons with the riser and gates, there was also the weight of the core that required handling at the same time, and it is therefore probable that the total handling capacity exceeded at least 200 tons.

Safety First.

We have received a copy of the second issue of "Safety First," the journal of the British Industrial "Safety First" Association. The journal contains the detailed proceedings of the first annual general meeting of the Association and many paragraphs of interesting and useful "Safety First" information. We regret to note that the original intention of publishing this journal monthly cannot be proceeded with. The Executive of the Association earnestly appeal for that measure of support which will enable the journal to appear at more frequent intervals and in a form worthy of the important propaganda it was designed to disseminate.

Publications Received.

We have received from the Anglo-Mexican Petroleum Company, Limited, 16, Finsbury Circus, London, E.C.2, a booklet entitled "The Story of Mexican Petroleum," being a reproduction of coloured photographic enlargements exhibited at their Stand No. 127 in the Oil Section of the Great War Exhibition, Crystal Palace, 1920. A general outline of the Mexican Eagle Oil Company's operations in Mexico are included.

The "Daily Mail" (Associated Newspapers, Limited) send us a prospectus of the forthcoming Efficiency Exhibition at Olympia, February 10 to February 26, 1921.

Many interesting articles, including "Profit Sharing," "Economical Production and Prevention of Waste," are contained in the "Industrial League and Council Journal" for June.

New Catalogue.

We have received from Messrs. The Automatic & Electric Furnaces, Limited, an advance copy of their new catalogue dealing with the Wild-Barfield Electric Furnaces. We note that these furnaces are now being designed in larger sizes to meet the increasing demand for mass production and also for the hardening of long articles such as cam shafts, tools, gear wheels, etc.

THE NORTHUMBERLAND SHIPBUILDING COMPANY, LIMITED, announce, as already notified in April last by the secretary of Baldwins, Limited, that the contract for the purchase of the ordinary shares in Baldwins, Limited, was entered into by Messrs. Sperling & Company as their agents. Negotiations are proceeding for the modification of the contract, and a further announcement will be made as soon as possible.

Springfield Steel Foundry, Glasgow.

The Springfield Steel Company, Limited, is the outcome of one of the oldest iron-founding businesses in Glasgow district, having been established by the late Mr. Robert Henderson rather more than half a century ago for the manufacture of malleable-iron castings.

The original melting plant consisted of a Siemens open-hearth furnace of 10 tons capacity. Later this was increased in length, and its melting capacity brought up to 20 tons, while a "Stock" converter of 2-3 tons capacity was also installed. This, in point of fact, comprises the melting plant as we find it to-day. The works themselves, however, have been entirely remodelled. This became absolutely necessary as, like so many other of the older foundries, they had outgrown their conveniences for economical production. Accommodation had to be provided for modern annealing furnaces, electric welding, a test house and laboratory—all recognised essentials in the equipment of the modern foundry. The office accommodation also was wholly inadequate. To provide for the latter a portion of the gallery above the foundry, which fronts on to London Road, has been converted into offices, and immediately below are the despatch and time offices and general stores. The manager's office overlooks the works and adjoins a well-equipped laboratory where all raw materials and samples from each cast are analysed and, in the case of the last, tests are also taken on an Olsen 50-ton machine.

So far as the moulding and casting operations are concerned, the Siemens and converter shops are entirely self-contained, the dressing and annealing shops being common to both. The Siemens department occupies a building 250 ft. long, and comprises two bays with spans of 42 ft. and 35 ft. respectively. The moulding floor is served by two Royce cranes of 15 tons and 10 tons capacity respectively. At the side of this bay is the cupola for bringing down the metal for core irons. All the moulding shops are equipped with pneumatic rammer and mould jarring machines; compressed air is also utilised for cleaning out the moulds previous to casting.

Moulding Bay.

The casting bay, which at the one end also serves for moulding, is served by two Royce cranes of 25 tons and 20 tons respectively. In this bay there are 10 special machines of the Company's design for moulding gears; this, it may be noted, is one of the works' specialities, and gears are cast up to 14 ft. in dia. Other interesting work going through the foundry at the time of our representative's visit included cane-crushing rolls, the weights of which ranged from 2 to 5 tons, a dredger tumbler weighing 7¼ tons, dredger bucket backs and other dredger parts, with an endless

variety of marine work castings. In this connection it may be noted that the steering gear tillers for the "Lusitania" and "Mauretania," which weighed 12 tons each, were cast at Springfield Foundry. The three-mould drying stoves and the core stove are coke-fired and fitted with electric fans and motors; in addition, there is a portable drying apparatus by Hardie & Gordon, fitted in the same way, which admits of large moulds being dried on the floor.

The furnace charging platform has been extended so as to make a common platform for the furnace and the producers, of which latter there are two—one

40 ft., two cranes serving the floor—a 20-ton Royce and a 15-ton Vaughan. In this shop are two Britannia moulding machines and a special machine for moulding small gears. It is noteworthy that only Belgian sand is used for moulding in this shop. The equipment includes two coke-fired drying stoves and a core oven.

At the side of the shop are two Tilghman's sand-blast rooms, served by a Herbert-Morris wall crane of 2 tons capacity.

The annealing shop is covered by a bay 150 ft. in length × 35 ft., and served by a 20-ton Royce crane. There are two annealing furnaces, one on the floor

CASTING BAY.

Purvis and one Stein & Atkinson. On the platform is also placed the Cochrane boiler which supplies steam for the producers and the stoves, and also a furnace fired by producer gas to calcine sand for the bottoming of the Siemens furnace, and to heat the mixtures or alloys which are added to the finished steel. The furnaces and producers are served by a 5-ton Royce overhead travelling crane.

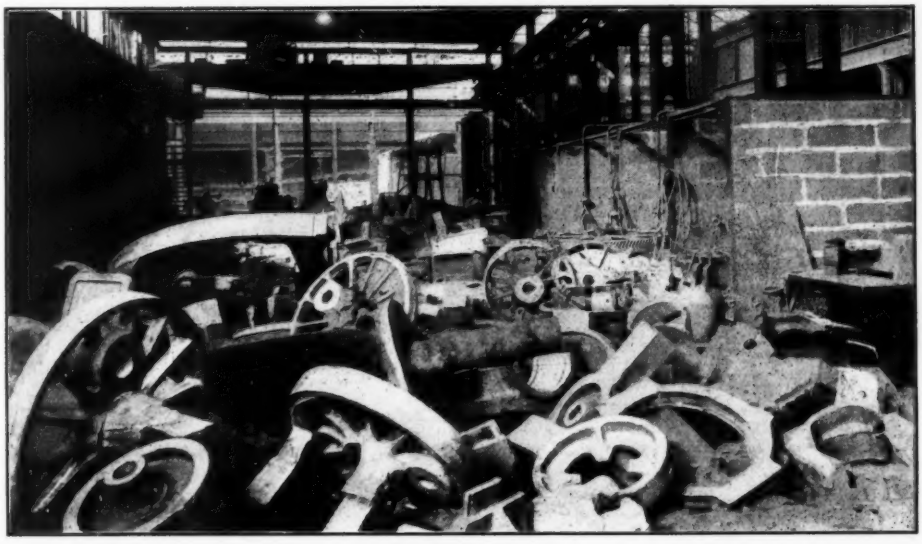
Raw material is brought in through a gateway from Springfield Road, immediately at the rear of the furnace where the stocking ground is situated. At the entrance is placed a Pooley 20-ton weighbridge, and on one side of the road—which extends completely round the works and is laid with a line of track and travelled by a loco crane—is the sand shop. Housed in a lean-to there is the usual pan mill and crusher, and a sand dryer is about to be erected.

The converter shop is covered by a bay 300 ft. ×

level, which has been in service for some years, and the second a pit furnace of the latest design, built by Messrs. Stein & Atkinson, and fired with producer gas. This furnace can be worked as a single chamber or as two chambers worked independently; it is usually worked as a two-chamber, the division wall only being removed when work of exceptional size has to be dealt with. The shop equipment includes emery grinders, two Noble-&-Lund band sawing machines, and five Clifton & Waddell cold saws. There are also two smiths' hearths, served by a Massey hammer.

The dressing shop is 275 ft. long × 45 ft., the runway carrying a 15-ton Marshall-Fleming-&-Jack crane and a Royce 10-ton crane. A compressed-air system is laid throughout the shop, the air mains being carried below the crane runway with down-comers on each column. There are three emery wheels installed; these, which were designed by the Company,

CONVERTER BAY.



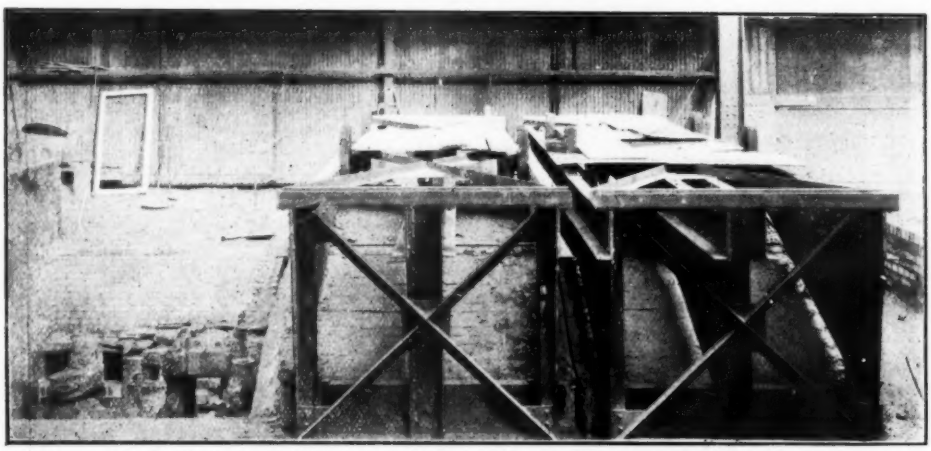
VIEW IN DRESSING SHOP.

are mounted upon universal-jointed swivelling shafts, and can thus be readily moved across the work to complete the removal of the risers which have been roughly cut off by the oxy-acetylene process. In the centre of the shop, and at the side where it adjoins the annealing shop, are three cubicles, which can be entered from either shop; one of these is devoted to oxy-acetylene cutting-off and the other two to quasi-arc welding.

In an annexe is a small engineering shop where works repairs are carried out and test bars prepared. Compressed air for the time being is supplied by an Alley-Maclellan belt-driven set of 250 cub. ft. capacity; this, however, is being supplemented with a set by the same makers of 600 cub. ft. at 100 lbs., which will be driven direct from a 120-h.p. motor.

The machinery is all driven by current taken from the Corporation mains.

PRODUCER AND CHARGING PLATFORM.



STEIN & ATKINSON ANNEALING FURNACE (COVER REMOVED OFF ONE FURNACE).

A fleet of "Sentinel" wagons is utilised for taking delivery of raw materials and delivering the finished product.

A new pattern-shop, complete with all labour-saving devices, is at present being proceeded with, and on its completion the establishment will be up-to-date in every respect.

The Froth Flotation Process for Separating Metals from Ore.

By James Scott.

In the recently adopted wet process of metallic ore concentration for foundry use advantage is taken of the fact that certain oils remain suspended in water, and are capable of being broken up into infinitesimally minute globules. It appears that some time ago a couple of Colonial engineers were experimenting with various oils in an attempt to separate the sulphides, oxides, and kindred valuable compounds from the mineral gangue accompanying them in the crushed state. They tested varying quantities of suitable oil stirred up in a large amount of water containing the finely powdered material; and eventually discovered that when a reasonable proportion of the oil was present, and the whole was violently agitated, the oil divided into globules which picked up the particles of metallic matter, while the useless gangue sank to the bottom of the vessel.

Hitherto it had been customary to cause the substance to sink, owing to its higher specific gravity, impelling the waste residue to travel away from it, and over the edges of the vessel. In the new method its use in the direction described, can be recovered for further application to similar methods. Otherwise the cost would become almost prohibitive. Sulphides, oxides, carbonates, and other compounds of the metals attach themselves more readily to oil than to water; whereas the mineral refuse prefers water to oil. Air films, or their absence, have an influence upon these tendencies.

For froth flotation the pulp is introduced into the first vessel, and is then vigorously stirred by mechanical means, thereby emulsifying the oil. The currents induced carry the various ingredients through the baffles into the flotation chamber, in which the gangue, or tailing, sinks to the bottom (afterwards being withdrawn through a hole, which is kept plugged when not required), while the oil globules, laden with metallic particles, rise to the top of the water, whence they can be removed with the help of paddles.

A large measure of the value connected with this process is due to the formation of the metallic particles themselves. The majority of these are flat, and perfectly symmetrical, these definite shapes being retained, no matter how small the substance is ground. This flakiness is traceable to the crystallisation of the original metallic compounds in the ore, a gradual, systematic building up of laminations having been in evidence. The particles of mineral gangue are less

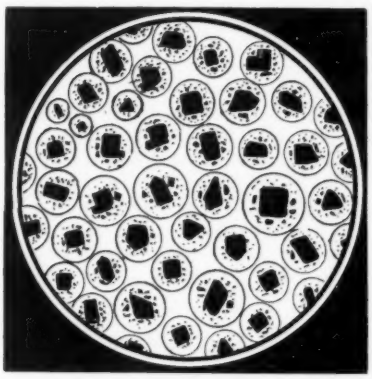


Fig. 1. One Twenty-fourth inch of a Froth Flotation Film, the Oil Globules of which are Uniform in Size, and ideally occupied by one or a few grains of Lead Concentrate.

Fig. 2. One Twenty-fourth inch of a Froth Flotation Film, the Oil Globules of which are full of grains of Lead Concentrate, and therefore tend to Sink.

the routine is practically reversed, the gangue sinking, while the metallic particles float.

Common flotation consisted of using forty to one hundred and twenty pounds of oil per ton of crushed ore in abundant water. The clustered globules then sank, taking with them the metallic powder. Then a stream of water was forced into the box, and the gangue dislodged from it.

For the purpose of froth concentration trough-like chambers filled with water are arranged in adjoining pairs, baffles being situated in the longitudinal dividing partition a little way down, so that the solids and oil can pass through from one vessel to the other; the openings of the baffles being about level with the top of the separating tank. The contrivances are partitioned off into individual compartments to assist the process.

At Broken Hill, Australia, heaps of waste material to the extent of 12,000,000 tons, had accumulated. The percentage of gangue equalled that of the lead and other sulphides, etc., present; so that ordinary gravitation practice was debarred. But by adopting the froth treatment the metal was fully extracted.

It is an important feature that most of the oil, after regular, their chance of proper crystallisation having been interfered with When broken up, the fractures are coarse and indirect, with the result that the pieces themselves are gritty and jagged. The thin plates of metallic compounds are thus facilitated in their power of adhesion to the oil.

The subjoined illustrations were prepared from the writer's own observations, and will enable the reader to understand the success of the operations under commercial supervision. We need not go into the theoretical side of surface tension, on which the activities of the substances depend. It will be sufficient to note that an oil, when poured on to water, will either divide into numerous globules, or else spread out as a thin film over its surface.

Supposing it exists in the latter condition. A sharp blow will split it, and the separated portions become rounded at the edges. Repeated strikings render it into still smaller sections, each of which will resolve itself into a definite spherical globule. After a while, however, as these globules come into contact with one another, the larger ones absorb the remainder, and finally the oil reverts again to the film form.

As an experiment a small quantity of creosote oil

XUM

(this is widely used for the purpose) was stirred up in a shallow jar of water along with some lead concentrates in which were some scraps of silver and zinc. It was noticed that this dust was so exclusively attracted to the oil globules that the water itself was entirely free from them. However much the contents of the receptacle were agitated, the particles continued to cling to the oil, thereby proving the practical efficiency of the process, which obviously does not allow much metal to be wasted.

In Fig. 1 is shown the appearance, as seen from above, of an ideal phase of the froth flotation, in which the oil has been so thoroughly agitated that it has been divided into globules so tiny that to the naked eye they are visible only as glistening dot-like points. Each contains merely one or two larger particles of metallic compound, but the whole bulk of solid which can in this way be held up in a small space is comparatively large.

Upon leaving these globules undisturbed for a while they united together to compose fewer larger ones, the particles of metallic compound then being resolved into a lesser number of groups.

In Fig. 2 is shown a cluster of completely filled oil globules, brought together by the coalescence of several smaller members in the manner just described. These are so heavy that they tend to sink; *but however large a globule becomes through mutual amalgamation of individuals, the metallic particles are always confined to them, and do not pass into the water.* Agitation of these black globules divided them into dozens

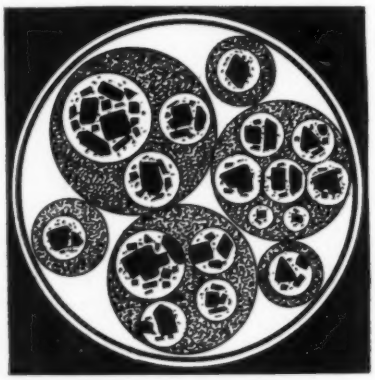


FIG. 3. ONE TWENTY-FOURTH INCH OF A FROTH FLOTATION FILM, THE OIL GLOBULES OF WHICH ARE COMPOUND, BEING INSIDE ONE ANOTHER, THE LARGER ONES CONTAINING WASTED MATTER FROM LEAD CONCENTRATE.

of smaller ones, in which the same total quantity of metallic matter was floated, as each bore only enough to be supported on the surface of the water.

Attention deserves to be drawn to the fact that each particle is enveloped in a thin film of air, which keeps it slightly away from its neighbours, hence the appearance of the slender spaces discernible between them. Of course, where a lot of particles overlie one another, such interstices get covered up.

In Fig. 3 is shown another stage of the phenomenon after prolonged agitation. In this instance larger globules of oil contained smalled ones, no doubt owing to the difference in density attributable to the action of the water. The larger globules were full of the tiniest imaginable specks, whereas the smaller ones were occupied by the usual-sized particles. It seemed that too much stirring must have been responsible for shaking off tiny scrape from disintegrated particles, making exceptionally fine dust. Whether this would be lost or not in the continued process it is hard to say. Collectively, it would be considerable in quantity, but it is still retained within the globules.

It is necessary to mention that in the illustrations the objects are depicted as viewed with the light shining up from below, therefore making the particles stand out dark. Shading of the oil portion of globules is prevented by equalisation of the illumination, so that they are wholly transparent

Thermostatic Metal.

Among the exhibits at the recent conversazione of the Iron and Steel Institute there was one of the thermostatic metal shown by the British Thomson Houston Company, Limited (77, Upper Thames Street, London, E.C.4). Thermostatic metal consists of two metals united firmly and permanently throughout their entire length. The two metals used have widely different co-efficients of expansion, and a bar made of them will bend with heat, and can therefore be used for making various devices for measuring temperature, superseding in many cases the ordinary thermometer entirely. Such device gives rapid, if not instantaneous, indication in a manner that can be read at a distance. A pointer actuated by the bending of such a compound bar can be made to move over, if necessary, half an inch with 1 deg. Fah. rise in temperature. The device has the advantage that there is no glass tube to break, and the reading takes not more than a second.

Pyrometers using thermostatic metal for registering high temperatures can be worked at a considerable distance, as the movement can be transmitted by a rod or a Bowden wire. In addition thermostatic metal could be used for:—(1) Liquid heat measures for all kinds of manufacturing purposes, registering from 100 to 600 deg. Fah.; (2) for electric cut-outs to replace fuses, and for devices to turn on gas or electric current for heating or lighting, or for other devices for temperature control or temperature compensation, such as oven thermometers, electric heaters, thermostats, scientific instruments, motor ignition control, battery charging control, electric signal control, computing scales, etc.

Thermostatic metal is made in standard thicknesses, ranging from 0.015 to 0.25 in., in widths up to 6 in., and lengths up to 36 in.

PIG-IRON FROM SCRAP STEEL.—The Engineering and Industrial Management describe experiments conducted by a Canadian steel foundry in the production of pig-iron from scrap steel. The first attempt to convert the pig-iron direct was made with 5,000 lbs. steel scrap and 250 lbs. ferro-silicon. This metal gave the hottest converter full of metal in the day's run, silicon absorption being 77 per cent. of that charged, and the steel resulting containing combined carbon 1.78 per cent., manganese 0.82 per cent., sulphur 0.044 per cent., and phosphorus 0.073 per cent. Since this initial success, the final two blows of each day's run have been made direct from steel scrap and ferro-silicon only, and all have yielded excellent castings. The amount of ferro-silicon used to make the artificial iron has been constantly reduced until it has now attained a minimum of about 160 lbs. of silicon per converter charge of 4,500 lbs. The saving effected by thus making pig from scrap steel, instead of buying pig-iron at present prices, has amounted to nearly 1d. per lb. of metal in the ladle. If the scrap is blown direct after melting with ferro-silicon, the saving is 1½d. Naturally the whole success of the process has been due to the use of the initially hot cupola and converter, coupled with the plentiful supply of good coke and of lump ferro-silicon, the latter preferably of the 50 per cent. variety.

The Castings for a Condenser.—I.

Ben Shaw and James Edgar.

THE PATTERN MAKING.

The old circular form of condenser was inexpensive compared with the type shown in Figs. 1, 2 and 3, because it was seldom necessary to make a pattern. Either the cope was swept out, or a sand barrel was made and the flanges, branches, and facings, nailed, or otherwise fastened to it. Only in the event of a large number of castings being required was a pattern made, and a taper had to be left in order that it would deliver from the sand; or, better still, a square-boxed centre was built with circled face which could be drawn into the mould after the box was withdrawn.

On nearly all modern high speed ships, however, the uniflux type of condenser, the construction of which will be described in this article, is installed. Until recently both the main and the auxiliary condensers of this design were built up from boiler plate. They are now frequently cast, and in this form are as cheap and equally as effective in use. Full wood patterns must be made for the condenser of this pattern and of the waterend and the doors. Not only is it necessary to make a pattern, but it is also necessary to make a corebox for the condenser. The condenser shown in the sketches is 5 ft. 6 in. long, and the metal is usually about ¾ in. thick, although it may be frequently thinner than this. The condenser may be moulded on its side or on end, but whichever way is adopted does not affect the construction of the body of the pattern. The moulder may be left to make his own joint, except for the branch on the top of the condenser, where the flange and the print should be made in halves and dowelled. This will act as a guide for the moulder when making his joint.

As frames for such a pattern should not be more than 18 in. apart, four ought to be made for the condenser, and they ought to be about 2 in. thick to ensure rigidity in the finished work. After the four frames have been half-lapped and screwed up, they ought to be screwed together and cut as one, as it will be quite impossible to plane four such frames separately and make them sufficiently accurate so that the work will be quite square. The cutting of the half laps may be done at a circular saw or on a half-lapping machine. It is easier to cut the corner of the frames diagonally than to a radius, and put on a sufficiently thick piece to allow the outside radius to be planed. The stays should be about 2½ in. thick, and planed to a parallel thickness and width. If these stays are warped or not straight in the length the pattern body will not be square when constructed; and if the sides are not built square with the ends, it is almost impossible to rectify afterwards.

In Fig. 4, which shows the skeleton of the body built and ready for the lagging, these frames are drawn as solid plates for the sake of clearness. In building the skeleton it is advisable to draw a straight line on the floor or on skids, and square a line on one edge of the frames, while they are screwed together. The length having been marked on the floor, and divided for the middle frame, the four frames should be fastened to the floor, the lines on the edge being placed to the centre line on the floor or skids. Blocks with screws into the frames and into the floor will hold the frames quite firm, while the stays are being screwed on. When the four stays that are above the floor have been fixed, the ends should be tested with a square before the skeleton is turned over, and the remaining stays fitted. If the condenser is a very large one, or the frames show any tendency to sag in the centre, it may be wise to fit three half-lap frames between the contour frames. The lagging need not be more than ⅞ in. thick and 9 in. or 10 in. wide, and should be left with open joints. It is as well to have one or two screws in each piece, but driving nails are quite good. In Fig. 11 the lagging is shown all round the frames; but with a spread branch, such as there is on this condenser, it is unnecessary to lag the top, which will be covered by the branch except a strip on either end. It is not necessary to build the branch on a bottom plate, as the pattern can be supported by means of temporary legs screwed to the end frames so that the face on which the branch has to be built will be in a horizontal position.

Large branches which are of irregular shape are invariably best made by making cross sectional pieces, which define the shape on the centre lines both in

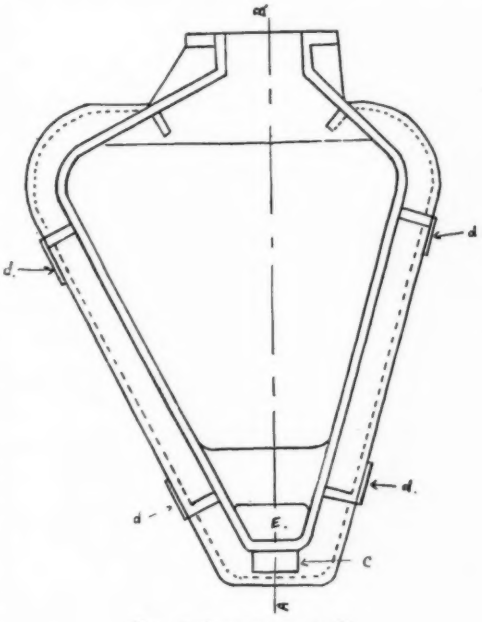


FIG. 1. SECTION ON A. B.

length and breadth. Fig 7 and 8 show these defining cross pieces checked so that one fits into the other. The outside rectangular shape in Fig. 9 is the shape on the condenser top, but on the left side of the centre line this shape alters to a diameter at the top, while on the right side the shape at the top is square. As it does not affect the utility of the branch, and it simplifies very considerably the pattern-making, the draughtsman can usually be persuaded to modify the design. If, however, the shape at the top must be a diameter, diagonal piece CC can be fitted and the shape between built of thicknesses of timber. The design on the left side of the centre line, Fig. 9, is less troublesome to shape. Grounds AAAAAA ought to be made on which covering timber can be screwed. It is a simple matter to calculate the shape of these grounds. The covering plate need only be ⅜-in. thick, the end ones being shaped and fitted, and the side ones being carried over the end edges. The shape of the end covering the plates can be drawn accurately by geometrical projection.

The body and the branch, which is really part of

the body, being finished, the details have to be made and fixed. The end prints are the biggest job. If

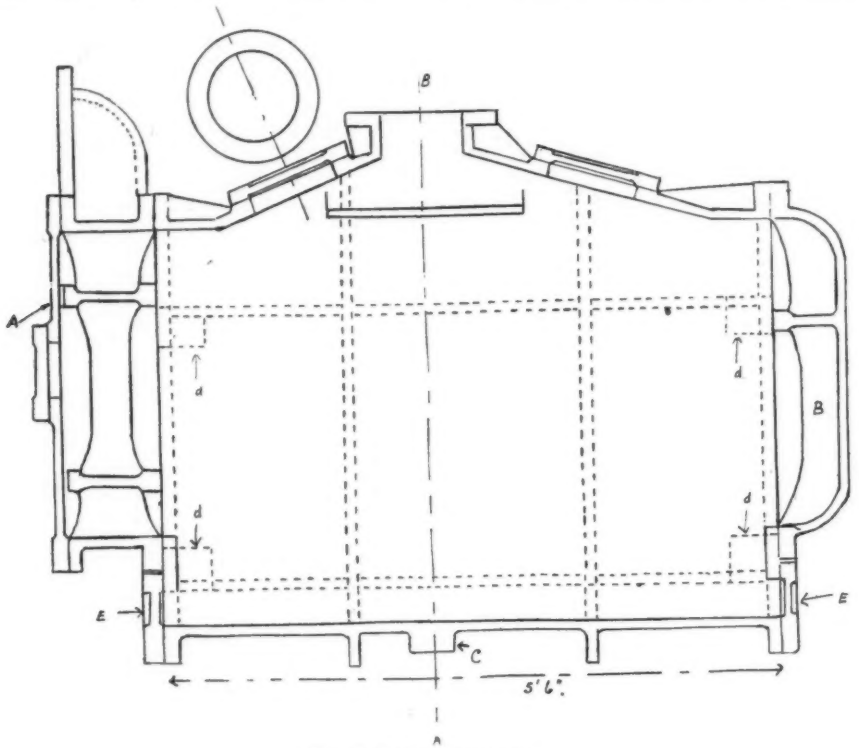


FIG. 2. FRONT ELEVATION.

the pattern is going to be moulded on its side, they should be 4 or 5 in. thick. The best way of making them is shown in Fig. 6: a top plate about 1 in. thick has timber 2 or 3 in. wide screwed to it to make up the thickness. The plates can be laid over the drawing board, and two temporary battens screwed to them, while the thick timber is fitted on the other side. The edge can be finished at the sand-papering machine.

The top and bottom flanges of the condenser ought to be divided so that they can be drawn into the mould when the body has been withdrawn from the sand. Indeed, this applies to all the ribs as well. A common failing of pattern-makers is to drive screw heads into the timber, which causes endless trouble in the sand, because the wood swells over the head and moulders have not sufficient tools for getting them out without destroying the pattern. Wiring loose pieces on a main body is a good practice, but if a pattern has a long journey to the foundry, the pieces are apt to get knocked off and lost. Cheese-headed screws are a great improvement over countersunk heads, and if washers are used there cannot possibly be any trouble afterwards

The straight ribs that run from flange to flange should be screwed on in one length, with a slight taper planed on each side, and the ribs that go round the body can be fitted between. It is advisable to ascertain which way the pattern will be moulded before screwing on the circular part of the big branch, because this part and the flange and the print ought to be in halves, as has already been explained, but the small branch, or boss, C Fig. 1 and 2 being small, may be made in one piece.

A special arrangement has to be made for moulding the feet dddd Fig 1 and 2. It will be quite impossible, even if the faces of these feet were left loose, to draw them into the mould. If they were made as

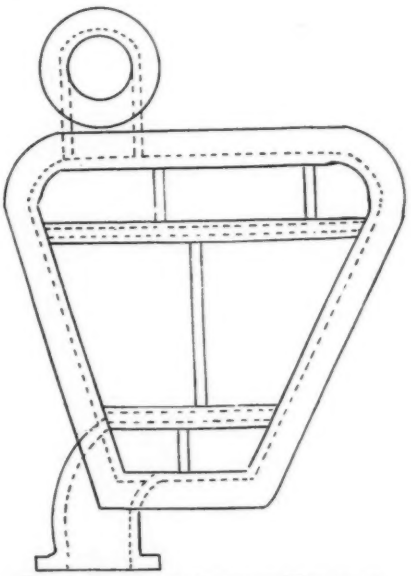


FIG. 3. END VIEW LOOKING IN WATER-END.

models of the finished casting the moulders would have to take them off in drawbacks, or by means of

loam cakes. A better way is to core out the spaces between the back of the face of each foot. The small end prints for the sight holes, EE Fig. 1 and 2, need not be as thick as the large prints. Screwing on the

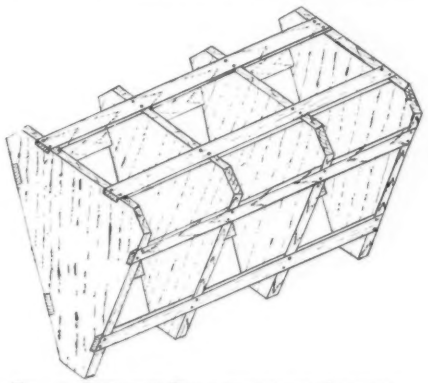


FIG. 4. SKELETON BODY READY FOR LAGGING.

various other small ribs is a simple matter, care being taken that the moulder can unscrew them if he wants to use them for making up his mould.

We have not dealt yet with one very important part of the pattern-maker's work, and that is making pro-

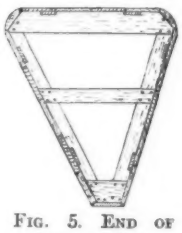


FIG. 5. END OF FINISHED BODY.

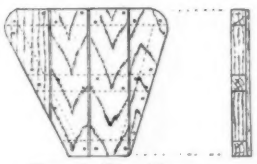


FIG. 6. END PRINT.

vision for drawing the heavy pattern out of the mould. It is not uncommon for pattern-makers to "forget" this part of their work, and it not only causes annoyance in the foundry, but may result in the pattern being badly damaged through a bad method being

FIG. 7. CENTRE SECTION PIECE FOR TOP BRANCH.

adopted. What the moulder frequently does is to loosen off a board on the top of his mould and put a rope or sling through one of the frames which has to stand the full strain. It is obvious that this is not good for the pattern. The sensible way is to put lift-

FIG. 8. CENTRE SECTION PIECE FOR TOP BRANCH.

ing plates on the bottom of whichever side will be under the mould, arranging them two in number, so that the strain will be equally borne by the various frames and stays. It is almost necessary to arrange for these plates while the main body is being constructed, as it may be necessary to bore holes through inside frames through which the belt can pass.

The finished pattern is shown in Figs. 10 and 11, and it will be noticed that the lagging on the body is left open-jointed. It does not matter how well-seasoned timber is, it absorbs moisture and swells, or dries and shrinks, and so when a pattern goes into

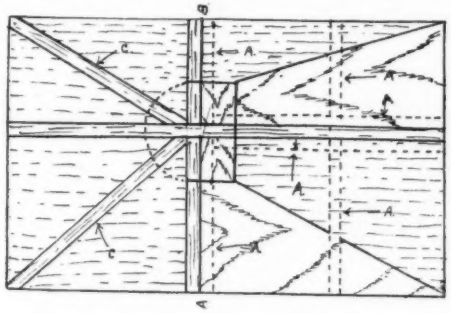


FIG. 9. SHOWING TWO METHODS OF BUILDING BRANCH.

damp sand, if the joints are close something must give, and the pattern becomes distorted. The only safeguard against this, apart from open joints, is to cover the pattern with a waterproof skin of paint and shellac varnish. But certainly the best way to preserve large patterns, if many castings are needed, is to leave open joints as well as paint and varnish them.

The best kind of core-box is shown in Figs. 12 and 13 and 24. It is necessary in constructing this core-box to make it possible for the moulder to make his

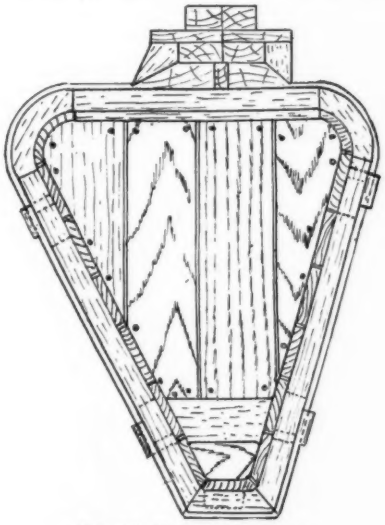


FIG. 10. FINISHED PATTERN.

grid easily and get in his lifters. If the pattern is to be moulded on end the core-box ought to be made on end, but the expense of making such a box on end would be almost prohibitive. The method shown in the sketch is preferable. The box is so made with runners on the end that a bed can be strickled off and the core made on this. The top of the box can be strickled off and the shape of the ends of the core-box will be as shown in Fig. 12. The bottom and side edges planed square are made up of width battened together, the top edges being cut to the necessary

angles. The sides are parallel and made in a similar fashion. Although they are not shown in the sketches it is advisable to screw battens diagonally from the sides to the ends on the bottom edges of the box, to hold it square.

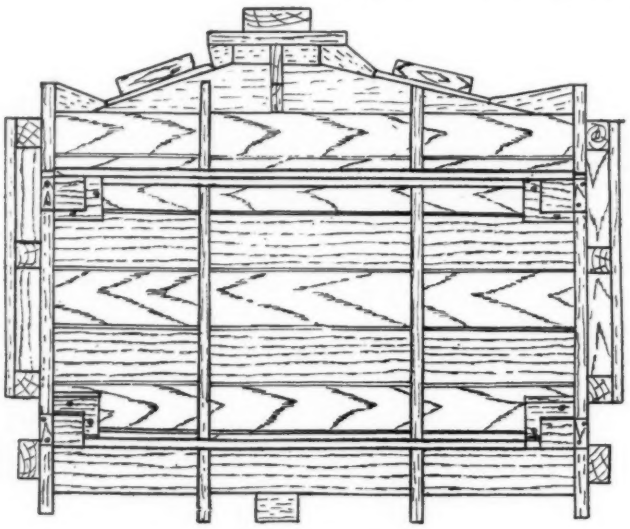


FIG. 11. FINISHED PATTERN.

The runners already mentioned are shown at A in Figs. 12 and 13. They are from 1½ in. or 2 in. thick and 2 in. or 3 in. wide. They must be well screwed, so that they will not move when the bed is being swept. It may be considered unnecessary to make the box square on the bottom with runners instead of shaping the ends to the shape of the finished core This could be done, but apart from the sides being very narrow, the moulder would have to prepare a bed for a large core, and this can be most conveniently done in the pattern-shop. The work saved in the pattern-shop would be wasted in the foundry. Blocks (B Fig. 13) are necessary to shut off the distance from the end of the main prints to the end of the core. Pieces are required to define the shape of the core at the main branch. Face plates screwed on shaped grounds are sufficient, and they should be cut to fit on the moulder's bed, and in line with the top edges of the ends, so that they will not be in the way of the strickle. Fig. 14 is a section on AB Fig. 13, showing the ends of the runners and a face view of the bevelled pieces for the branch.

It is important before sending a job such as this to the foundry that it be well marked. Practically every piece of the pattern and the core-box will be taken off by the moulder, as if it is not necessary for the purpose of drawing from the mould, it will probably be necessary to assist him in making up corners, and if well marked there is no difficulty in screwing up again. Chiselled V-cuts are much better than lettering, as the grain does not rise and fill them, and if they are also coloured the task of putting the pattern together after each casting has been made is made more easy.

The Doors and Water-end.—The method of making the patterns for the doors and water-end depends upon the number of castings required. The flat door shown at A (Fig. 2) is simply a large plate with facings on either side The cheapest pattern for this item is constructed by simply placing boards side by side, and checking cross battens in. A much better pattern is obtained by making a half-lapped frame and on the inside of each piece of timber a check can be cut out at the saw and the centre filled in with boards. It may be necessary to inset a batten across the boards if the job is very large Fig. 15 shows this door pattern quite finished with the facings and the sight-hole print screwed on. Another method, and quite a good one, is to make a simple frame and leave the spaces to be strickled out by the moulder.

The pattern for saucer-shaped door B (Fig. 2) at the other end of the condenser from the water-end can be made by at least three different methods :—(1) The

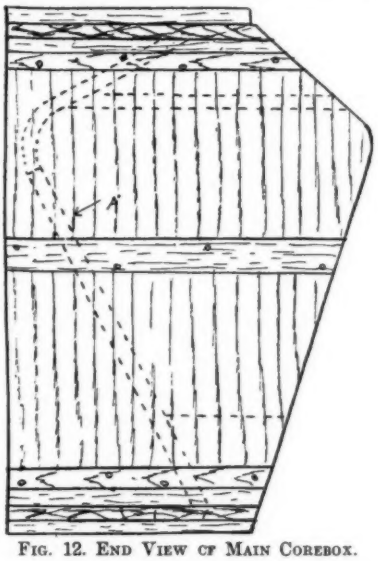


FIG. 12. END VIEW OF MAIN COREBOX.

use of a block pattern with a core-box, or (2) the use of a shell pattern. The method usually preferred is the use of the skeleton principle of construction. If a standard pattern were required the block pattern is certainly the best. In making a block pattern a half-lapped frame similar to that used in the previous pat-

tern is the foundation, but the cross centre battens may have to be measured in, so that they will support the structure. The size of the top frame A (Fig. 16) is determined by the size of the radius of the curve which connects the top plate with the flange. The top plate can rest on supports the necessary width,

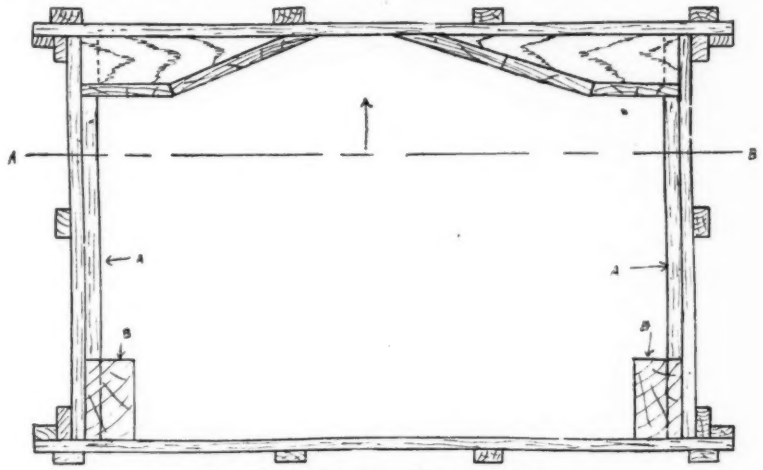


FIG. 13. TOP VIEW OF MAIN COREBOX.

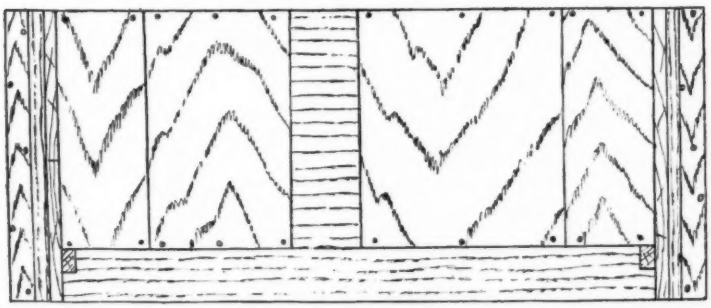


FIG. 14. SECTION OF BOX ON A. B. (FIG. 13) LOOKING IN DIRECTION OF ARROW.

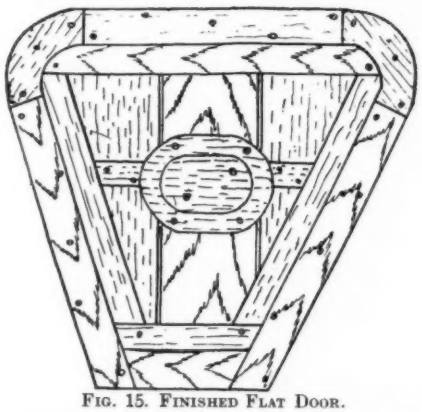


FIG. 15. FINISHED FLAT DOOR.

which are screwed to the flange, and are shown dotted in the sketch of the finished pattern Figs. 16 and 17. Four pieces have to be made for the curve, and to reduce the timber cost, grounds ought to be used with a face piece screwed on. The corners are best fitted in solid, and when this is done the pattern is complete except for the print, which need not be more than $\frac{3}{4}$ in. or 1 in. thick, as it is merely a guide for setting the core. This makes a really strong and light pattern.

The core-box for a solid door takes a good deal of timber. A bottom is necessary, and an outer frame is necessary inside which the core-shape can be found. Fig. 18 is a suitable box. It is a skeleton box and requires little explanation. The depth of the sides should be at least $\frac{1}{2}$ in. deeper than the core, so that the centre piece $\frac{1}{2}$ in. thick can be fixed on the bottom. This obviates feather edges, and it is easier for the moulder to make up the box with sand. The grounds may be cut from a template, and the joint resting on the grounds should be about $\frac{3}{4}$ in. thick. If a solid box were required in the foundry the most practical way of making it would be to fill in with pieces like Fig. 19, and in the long run this would prove a cheaper box than that made skeleton.

A shell pattern need not be considered in detail. This form of pattern is difficult to use, and as a pattern is not durable. A really good skeleton pattern can be made which will stand moulding many times, and it has the big advantage over a block pattern that it ensures the correct thickness of metal. Fig. 20 is a plan of a skeleton pattern, and Fig. 21 is a view looking on the inside, but not showing the skeleton work, but merely the ribs with the loose pieces wired instead of screwed on. The flange ought to be built of two thicknesses and an open frame made for the

top. The skeleton pieces, which should be about 2 in. thick and 3 in. or 4 in apart, should be screwed on runners, which makes accuracy less a matter of chance in building and makes rebuilding the pattern an easy matter if the moulder wants to take any part of it to pieces.

When all the parts have been made, the flange ought

FIG. 16. SECTION OF BLOCK PATTERN FOR COVER B.

to be set to centre lines on a flat building board or on the floor, and screwed down. The top frame, which may rest on temporary supports, should be squared into position, when it is a very easy matter to screw

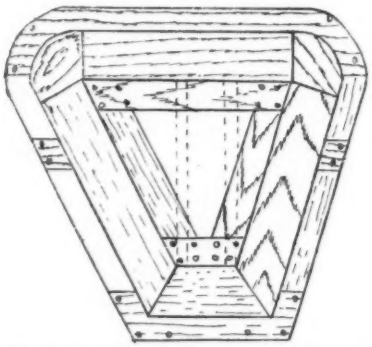


FIG. 17. PLAN OF BLOCK PATTERN FOR COVER B.

the skeleton sections in their places. The spaces between the skeleton pieces will be strickled out by the moulder. Lifting lugs are usually cast on these doors. The ribs on the inside are preferably screwed

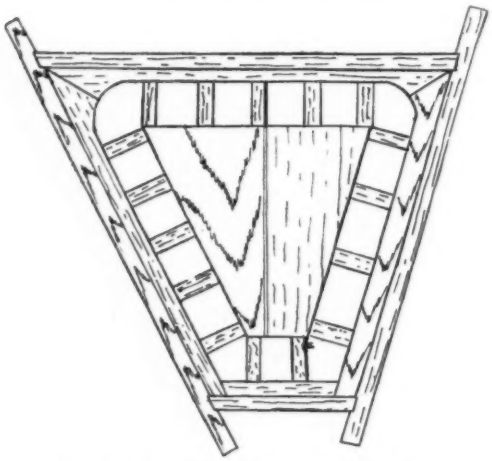


FIG. 18. PLAN OF COREBOX FOR COVER B.

from the outside of the pattern, so that the moulder will have no difficulty in loosening them off. The side strips (AA Fig. 21) can be drawn into the rib. A pattern thus made will be found to be very rigid.

The only remaining casting, apart from the minor details, such as sight-hole doors, is the water-end or water-way. This has two branches, an inlet and an outlet. Like the saucer-shaped door it may be made in a variety of ways. Sometimes when they are very large, and the metal is thin, a block pattern is made, and the mould is wood thicknessed. The construction

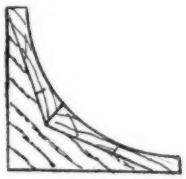


FIG. 19. RADIUS PIECE FOR COREBOX FOR COVER B.

of the pattern in such a case is identical with the construction of the condenser pattern. Although the size of the work ought to determine to a very great extent

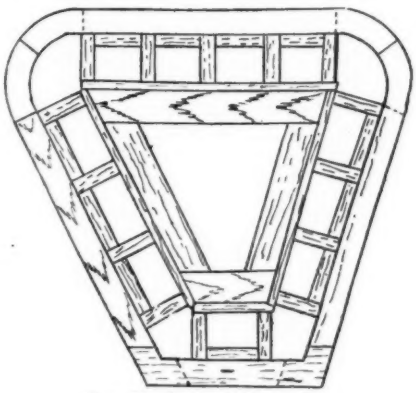


FIG. 20. PLAN OF COVER B.

the way in which it is to be made, the judgment of the craftsman has to be exercised, and he has to take into consideration as well as size the thickness of the

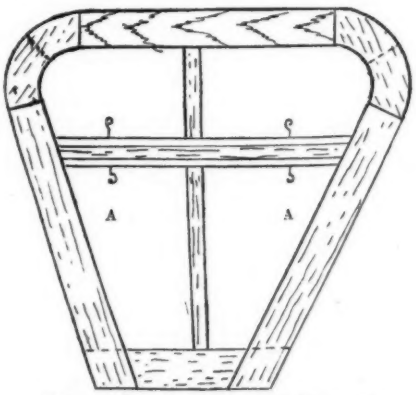


FIG. 21. INVERTED PLAN OF COVER B.

metal and the quality of the pattern necessary. For a condenser of the size we are considering, and of which the metal would be ¾ in or so thick, it is as well to make a skeleton pattern, always providing that a large number of castings are not wanted. If so, then a block pattern ought to be made and also a core-box. In passing, it may be said that the core-box would be

made in a very similar fashion to the skeleton pattern which we are about to consider.

Flanges of two thicknesses are made with stays between, and the inside is lagged with ¾ in. or ⅞ in. timber. It is necessary to leave sufficient taper, and one great advantage of the skeleton pattern is that no taper is necessary. The first step is to make two flanges, and these are connected by means of stays checked into them, and which are the thickness of the metal. A ¼-in. shoulder on these pieces will keep the flanges the correct distance apart. It will probably be necessary to put more stays than are shown in the sketch to support the branches. The moulder would complete the mould with the aid of a strickle.

Another form of construction which is more suitable for smaller patterns is to make a shell pattern on exact model of the required casting except for the branches, and these must, of course, be cored out. The

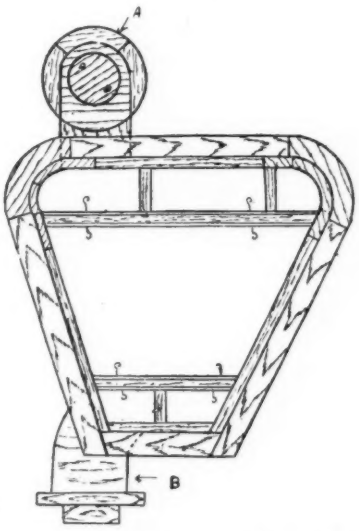


FIG. 22. FINISHED SHELL OF WATER-END PATTERN.

sides of such a pattern might be screwed together, but it is advisable to build two thickness section pieces for the corners, which can be set in top and bottom. The bottom flange ought to be made in pieces so that it can be drawn into the mould, but the top flange is better built of two thicknesses, thus helping to hold the framework of the pattern together. The internal ribs are easily fitted; the loose pieces are wired on in the same way as those in the cover.

Very often the branches are shaped from a large diameter on the outside to a rectangular shape breaking through the metal of the water-way. These require very great care when making the core-box. In the case of very irregular shapes the pattern-maker gets out of the difficulty of making a core-box by leaving the moulder to clay or sand thickness the mould. Wood thicknessing is, of course, only practicable on flat faces. The branches under consideration are easily made. In the case of branch A the face of the flange will be at the bottom of the mould and the flange, as will be seen from the sketch, is made so that it can be drawn into the branch. The branch B may be made solid with the flange and print in halves. The branches are frequently made square between the flanges, to obviate the awkward corners and thick metal resulting from a diameter breaking through between parallel flanges, and this modification does not affect the efficiency of the casting. The best and quickest way of finishing a circular bend is to plane the wood to a parallel thickness, grind it to lines inside and out, and then pare from sides to top at an angle of 45 deg. Most large pattern-shops have nowadays a wood-working machine on which bends can easily be shaped. It is an advantage to fit prints inside the water-way to help the moulder setting his cores. If the boxes were large, skeleton boxes might be made for them, but when they are as small as those we are considering it is as well to make them solid.

The National Physical Laboratory.

The Annual Inspection of the National Physical Laboratory by the General Board took place at Teddington on Tuesday last, when Sir Joseph Thomson, President of the Royal Society and Chairman of the Board, Sir Arthur Schuster, Vice-Chairman, and other members welcomed a large and distinguished gathering at the Laboratory. The present Director of the Laboratory is Sir Joseph Petavel, K.B.E., F.R.S., who succeeded Sir Richard Glazebrook last September.

The Laboratory is now organised in seven departments—physics, engineering, aeronautics, metallurgy, electricity, metrology, and the William Froude National Tank for tests of ship models. In this department tests are being conducted into the effect of loose oil in large compartments on oil cargo steamers. The physics department includes divisions for heat and thermometry, optics, radium and X-ray work and tide-prediction. Additions to the existing buildings will shortly be erected, notably an extension of the engineering department. The Admiralty also propose in future to make fuller use of the facilities afforded by the Laboratory, and are erecting a building for special Admiralty work immediately adjoining it.

The normal work of the Laboratory has now been resumed, one of the most important features being the maintenance of accurate standards of measurement, in which there is much leeway to be made up.

The apparatus and experiments shown included many features of interest. In the engineering department were exhibited the various methods of determining the "fatigue" resistances of materials, under the repeated application of stresses of various kinds, and also a model of a proposed testing machine, on the Lanchester principle, for determining the efficiency of spur and bevel gears, etc. The metallurgy department exhibited the different methods and furnaces employed in the production of alloys and the investigation of their properties, while in the refractory department was given a demonstration in the extension of refractory tubes for enclosing thermo couples. Other items of interest were special machines and methods developed during the war for the more accurate measurement of gauges of various kinds, including screw gauges, the testing of miners' lamps and of ships' navigation lights, new methods of measuring refractive indices, and apparatus for measuring humidities at low temperatures.

INSTITUTE OF PHYSICS.—The Institute has been founded by the co-operation of the Faraday Society, the Optical Society, and the Physical Society of London. The first Board of Directors of the Institute is constituted from representatives appointed by the Council of the societies mentioned. The Institute has already received promises of support from leading physicists, and the initial expenses are covered by a guarantee fund amounting to over £1,200. The first president of the Institute is Sir Richard Glazebrook, Sir Robert Hadfield is treasurer, and Professor A. W. Porter, hon. secretary. Mr. F. S. Spiers is secretary, with offices at 10, Essex Street, Strand, London, W.C.2.

XUM

Aluminium Alloys in the Foundry.

Before the Coventry Branch of the Institution of British Foundrymen recently, Mr. E. Carey Hill, technical director of Aluminium Foundries, Coventry, lectured on the above subject. Mr. A. Harley (President of the Branch) was in the chair.

The author said that the widespread use of aluminimum in petrol-engine and motor-car construction made the metal deserving of special study. That it had not received until recently much attention was not surprising when they remembered that it was only first separated as a metal in 1827, and was not obtained in a perfectly pure condition until 1854. Even then it was some years before its possibilities began to be fully realised.

The outstanding property of aluminium, of course, was its lightness. The specific gravity of the pure metal when cast was 2.56, which was but slightly above one-third that of iron. When rolled or drawn the specific gravity was 2.71, as compared with copper 8.95. The specific heat was 0.212, and the melting point 1,210 deg. F., or 654 deg. C. The peculiar whiteness of the metal was very striking. Aluminium had very high malleability and considerable ductility. Its tensile strength in the pure state was from 7 to 8½ tons per square inch. It was too soft when unalloyed to be used in engineering design, but when alloyed this softness was corrected and the tenacity considerably increased. It did not corrode at all readily in the pure state, and even when alloyed a dry atmosphere had practically no effect upon it. Its contraction during cooling was somewhat high, about 3-16 in. to the foot, and this property called for very careful treatment in the foundry for the successful production of castings.

Having alluded to the many uses of aluminium in modern industries, Mr. Hill said that treatment of aluminium in the foundry for the production of sound castings had now reached a stage of considerable perfection. The principles to be adhered to if good results were to be systematically obtained were governed by the following facts:—(1) The high contraction of aluminium during cooling; (2) the peculiar stage of plasticity through which it passed between liquid and solid, similar to common solder; (3) its very low tenacity at high temperatures. These peculiarities varied slightly in the different alloys, but the principles he spoke of might generally be applied to all light aluminium alloys in sand casting. Castings were required for structures of intricate design, in which the thicknesses varied in different parts of the design on account of bosses, bearing housings, flanges, facings, etc. This at once introduced complications during the cooling processes after the castings had been poured.

He had mentioned the plasticity of aluminium alloys during solidification. Taking as an example a simple form in which there were two thicknesses, it was clear that the thin portion of the casting, owing to its smaller mass and greater relative area for radiation, would completely solidify while the thicker portion was still plastic. Consequently, contraction would commence in the thin portion, which might thus exercise considerable stress on the junction of the thick and thin portions. The latter, having at this stage not yet acquired any tenacity, was unable to resist the stress, and in its plastic state was pulled partly asunder at the junction. The result, after complete solidification, had a curious opened-out, spongy appearance, and was generally called a "draw." This might be prevented by placing a chiller in the mould on the face of the thick portion.

Taking a more aggravated instance, in which the thick portion was much heavier, and the metal was run through the thin part, it would be found that the thick part would fail to keep up to shape owing to contraction, whilst a very open, spongy surface would become apparent. In such a case compensation for the shrinkage during cooling was provided by the addition of feeders or risers. The mass of the feeder being greater than the mass of the thick part to which it was attached, the feeder would remain liquid longer, and as the casting skin solidified and thickened, the heart, still liquid, would be supplied from the feeder, thus preventing the effects of shrinkage from deforming the skin or shell which solidified first. A draw would become apparent in the feeder, where, however, it would do no harm.

The feeder should be of very ample dimensions, and should exceed in mass the portion of the casting to be fed, or the feeder would solidify first and draw its supply of metal from the casting, thus making matters worse than before. This error was not infrequently committed by the moulder, who was sometimes apt to attribute virtue to a feeder irrespective of its size in relation to the casting it was designed to feed. It might perhaps be said that these were simple and elementary principles of founding applying to most metals; but the peculiarities of aluminium were so accentuated that it would be difficult to over-emphasise the importance of great care in applying those principles in the production of aluminium castings.

Pure aluminium, said the lecturer, melted at a temperature of about 654 deg. to 660 deg. C. Practically all the aluminium alloys commonly used melted at a still lower temperature; consequently, there was no need to raise the temperature of the metal at all high, probably not above 700 deg. C. to 720 deg. C., for the production of sand castings of any nature. It had been proved that the physical properties of the resultant castings were very greatly influenced by the temperature to which the metal was raised in the furnace, and still more perhaps by the temperature at which the casting was poured. Excessive heating in the furnace produced oxides, the presence of which reduced the tenacity of the casting and had a generally bad influence on the behaviour of the metal, encouraging drawn places and cracks during cooling.

It was found also that the best results in regard to physical tests could not be obtained unless the pouring temperature was carefully watched and kept as low as possible. It was, of course, impossible, owing to the variety of alloys used, to specify any temperature which should be adhered to, but it should be remembered that the lowest possible temperature for casting should always be adopted, consistent with sufficient fluidity to run the particular castings and at the same time to allow any air bubbles formed during pouring to escape from the metal before it solidified. It would probably be found that a temperature of from 680 deg. C. to 700 deg. C. would give satisfactory results for general foundry work, with normal alloys containing about 85 to 90 per cent. of alu-

minium. The liquidus curves on the aluminium-copper and aluminium-zinc thermal diagrams gave an idea of the melting points of these two series of binary alloys, and helped to indicate what was likely to be a suitable temperature for foundry working.

A point for very careful supervision in the foundry was the manner of making the cores for cored castings, and the materials used for them. Wherever possible, it was desirable to use green-sand cores, as they offered less resistance to the contraction of the casting. They should be as soft as consistent with satisfactory working. In many cases, however, dry-sand cores had to be resorted to, and then a sand mixing should be used which would give the largest degree of collapsibility to the core after the casting had been made. He had always found that better results were obtained, especially in large castings with complicated coring, when the runner was placed on a level with the bottom of the mould. The metal poured in thus steadily rose and pushed the air before it upwards through the risers. The alternative entailed the rapid descent of the metal through the moulds to the bottom, and this gave greater risk of the displacement of cores and caused a certain amount of air to become mixed up with the metal, with, consequently, increased risk of blowholes.

With regard to the melting and mixing of alloys, it was the general practice, where copper was to be included, to first make a preliminary alloy containing 50 per cent. copper and 50 per cent. aluminium, by first melting the copper and then adding the aluminium piece by piece. He had seen it suggested that a better method was to make the composition of this preliminary alloy, that of the eutectic, namely, 33 per cent. copper and 67 per cent. aluminium. The 50 : 50 alloys melted at a low temperature, about 580 deg. C., and consequently at a much lower temperature than pure aluminium. It could therefore be conveniently added to the charge of metal in suitable quantities without any excessive heating being required. It also had the great advantage that it was exceedingly brittle, so that an ingot would break if dropped on a hard floor. It could therefore be easily broken up into small pieces, so that the exact weight required for each charge could be readily prepared. Zinc to be included in the alloy should be added last, when the rest of the charge had reached the temperature required. Great care was needed to ensure all the zinc being melted and thoroughly stirred, otherwise the metal at the bottom of the crucible would be found to be rich in zinc.

The temperature, 720 deg. C., suitable for the maximum of the metal in the furnace could be approximately gauged, after experience, with the naked eye, by the amount of red light given out. At a temperature of 670 deg. C. there was almost no light given out in daylight, the metal reflecting its natural silvery-white lustre; but to see this truly it was necessary to push aside the film of oxide which formed on the surface, and which at this temperature was itself variously coloured, according to the composition of the alloy.

The speaker did not suggest, however, that such crude methods should be relied upon, as the importance of the pouring temperature, especially for castings whose physical properties must attain fixed standards, necessitated the continual use of instruments of scientific precision for temperature measurement. The pyrometer used for this purpose had not to stand any temperature above, say, 900 deg. C., and it was consequently possible to use a thermo-couple of common metals, such as iron and constantan. These, being comparatively inexpensive, might be renewed whenever deterioration necessitated it. It was better, even so, to have the thermo-couple well protected by a steel tube, as workmen hesitated to use freely an instrument which was easily damaged. The error in reading temperatures caused by the use of the protecting tube could easily be found by experiments and allowed for. It was well to test the accuracy of the pyrometer at fairly frequent intervals. This could be done by allowing the instrument to stand in molten tin and recording the temperature at frequent intervals of, say, every half-minute.

The break in the otherwise continuous downward curve should occur at 228 deg. C., the melting point of tin.

Dealing with the melting of aluminium, Mr. Hill said owing to the comparatively low melting point of aluminium and its alloys, the metal can easily be melted in almost any type of furnace. Probably the crucible type has been more generally used in foundries producing sand castings than any type without crucibles.

In the early days of the industry, about 20 years ago, when the birth of the motor-car trade first created a demand for aluminium castings in considerable quantities, the aluminium alloys required were usually melted by the brass furnacemen in one of the old-fashioned coke-fired pit-type furnaces which were then used for melting brass and bronzes. The rapid growth of the demand for aluminium castinge in increasing quantities soon necessitated special provisions being made for the melting of the metal, and for the castings to be made in separate foundries allocated solely to aluminium alloys; but still for a time the coke-fired pit-type furnace was adhered to, though the size of the furnace was increased to admit of larger-sized crucibles being used, the crucible having a 500-lb. copper capacity being one frequently adopted. This size crucible would take 150 lbs. of aluminium. In this case, of course, the weight of the crucible with its charge of metal was too great to allow of its being conveniently or economically lifted from the furnace after the melting of each charge was complete. The practice was therefore adopted of ladling the metal from the crucible into smaller carrying ladles.

Continual efforts to achieve greater economy resulted in the introduction of various devices to render these coke-fired pit-type furnaces more efficient, to enable them to melt a greater number of charges per day with a lower consumption of fuel per ton of metal melted. Such devices included special forms of fire-bars allowing greater ingress for the air to the zone of combustion around the crucible, as well as special casings to contain the furnaces, designed to permit of a freer passage of air into the furnace pits, and finally the coke-fired furnace was brought to its present, and probably greatest, degree of perfection with the introduction of the tilting furnace, having an air-blast provided either by a blower or a fan. Many furnaces at present in use had electrically-driven fans attached.

In the meanwhile the substitution of gas as a fuel enabled much greater strides forward to be made in the search for economy. Some of the earlier gas-fired furnaces retained the form of the crucible pit-type of furnace.

XUM

A type of furnace with which the speaker had had considerable experience used town gas as a fuel. This was not compressed above the town pressure, but was passed by a rotary fan into a mixing chamber where an exactly equal quantity of air was introduced, the proportion of gas and air being very delicately controlled by balancing valves, the mixture passing on thence to the furnaces. The furnaces were of the tilting variety, no crucible being used, thereby eliminating entirely the very considerable expense of the continual replacement of burnt-out crucibles.

Oil is also used very successfully as a fuel for furnaces, and the furnaces are often of a very similar construction to those using gas fuel.

Plant for Pneumatic Moulding Machines.

Dealing with the pneumatic moulding machines used for aluminium founding, the lecturer gave an illustration of an air-compressor belt-driven by a 50-h.p. electric motor. The cooling was effected by a mechanical water cooler mounted on a platform overhead, through which the water was circulated by a pump. The compressed air was stored in a cylindrical receiver erected in a vertical position adjacent to the compressor.

The demand for pneumatic power for the foundry was nearly always very intermittent, and consequently it was a great advantage to have a large storage capacity in order that the air-compressor might be working to advantage and storing up compressed air when the demand had stopped. Of course, there was a limit to which the air might be compressed in the receiver. When that limit was reached—in the case mentioned 100 lbs. per square inch—a governor valve operated by the compressed air in the receiver, conducted along a small pipe, came into operation and automatically closed the inlet valve of the air compressor. The compressor would then run free, absorbing very little electric power, till the compressed air in the receiver again fell below the limit.

The Alloys of Aluminium with Copper.

The aluminium-copper alloys were of particular interest because at both end of the series—namely, the alloys rich in copper and those rich in aluminium—were found alloys which had properties of great value to the engineer. Taking first the alloys rich in copper, it was found that from 0.1 to 11.0 per cent. of aluminium the properties were such as to render the alloys of value. The most prominent alloy of this group was that containing 90 per cent. copper and 10 per cent. aluminium and known as aluminium bronze. With from 8 to 10 per cent. aluminium were found relatively high tenacity, a fairly distinctive yield point of from 12 to 20 tons per sq. in. and an ultimate or breaking strength of 30 to 35 tons per sq. in. In making castings of these alloys, the aluminium might be added direct to the copper without making a preliminary or intermediate alloy. It was important to ensure thorough stirring and to watch the casting temperature. The contraction varied from 1.83 per cent. to 2.34 per cent. Alloys in this group were nearly incorrodible by sea water, either alone or when attached to steel, and were only slightly corrodible in ordinary fresh water.

The alloys in the next group, containing from 12 per cent. to 85 per cent. of aluminium, were of little use, being extremely brittle, but it was interesting to note that with 15 per cent. aluminium very great hardness was attained—Brinell No. 539, which was equivalent to the hardness of the steel containing 0.45 per cent. carbon quenched in water at 20 deg. C.

The final group, containing 1 per cent. to 15 per cent. copper, were of great interest. The alloy, containing 8 per cent. copper, had practically become the standard alloy used in the U.S.A. for motor castings. It had a specific gravity of 2.85. Part of this group, from 3.75 per cent. copper up to 12 per cent. copper, had moderate tenacity, giving yield points of from 5 to 7 tons per sq. in. and ultimate strength of from 6 to 10 tons per sq. in.; but by mechanical treatment great improvement might be achieved. Rolled bars containing 3.76 per cent. copper had been made to give 18.5 tons yield, and 20 tons ultimate, with an elongation of 7.5 per cent. An alloy containing 10 per cent. copper was much used in this country for castings in which fresh water had to be contained, such as radiator tanks and water pipes, on account of its close grain. Alloys in this group withstood very high hydraulic pressures most satisfactorily. They were practically uncorroded by fresh water, but were rather strongly corroded by sea water. It was of great importance in melting any of this group of alloys to avoid overheating. An alloy containing 7 per cent. copper was often used for production of die-castings.

Alloys of Aluminium and Zinc.

Aluminium-zinc alloys were of very great value, as they attained considerable tenacity. In the preparation of the light aluminium-zinc alloys, although care must be taken, there was not so much danger of loss of zinc by volatilisation as in the preparation of brass, aluminium having a much lower melting point than copper. If the aluminium was kept at a temperature only slightly above its melting point, and the zinc entirely submerged in the aluminium when alloying, the loss would be surprisingly small. The group of principal interest in this series was that containing from 1 per cent. to 25 per cent. of zinc.

It had been alleged that these alloys were liable to very serious defects, such as corrosion, cracks and disintegration when aged. But this allegation had not been very materially supported by experiments conducted on alloys made from pure metals, and it was probable that impurities introduced in the zinc had at times been the cause of such defects. It was of great importance that zinc of high purity be always used. The alloys of this group were very fluid when molten. As to tenacity, the yield point rose from 2½ tons to 13 tons per sq. in. at 25 per cent. zinc in sand castings. This tenacity seriously decreased with the rise in temperature.

Alloys of Aluminium, Zinc and Copper.

The ternary alloys of aluminium had considerable possibilities, and one or two were very largely used. There had not been the same amount of research work conducted with regard to them as with regard to the binary alloys. By the addition of a small percentage of copper to alloys containing from 5 to 25 per cent. of zinc, the tenacity was increased and greater rigidity attained. An alloy consisting of 2 to 3 per cent. copper and 8 to 10 per cent. zinc was very largely used in the casting of motor parts and was the English equivalent to the American 8 per cent. copper alloy. Greater tenacity was attained by increasing the zinc con-

tent right up to 20 per cent. and even 25 per cent., and the alloy possessed no corresponding disadvantages, except increased specific gravity. The present demand was for an alloy not to exceed about 2.9 specific gravity. It was possible that this was a mistaken attitude, as the increase in tenacity outweighed the slight disadvantage. Surprising results could be obtained by working these alloys. A half-inch hot-rolled bar of an alloy containing 25 per cent. zinc and 3 per cent. copper would give a yield point of 27 tons per sq. in., a breaking strength of 31.7 tons per sq. in., and an elongation of 20 per cent. on 1 in. The specific gravity was raised by this treatment to 3.29. Remarkable results had also been obtained with an alloy containing 20 per cent. zinc and 3 per cent. copper; special processes had been applied for the production of bars of this material, which was difficult to roll. It was considerably used in the foundry for castings in which greater tenacity was required and low specific gravity not of importance.

Other Aluminium Alloys.

Alloys containing tin, often with copper added, had been used to some extent in France and by a few manufacturers in England; but they had not come into general use. It had been said that alloys of tin did not show quite so pronounced a tendency to draw as the zinc alloys; this, if so, might be due to a diminution in the contraction when tin was present in sufficient quantity.

Nickel was used with a view to producing a very light, tough alloy, and had been tried, the lecturer believed, in bicycle rims and similar parts. He had himself found that, in spite of the high melting point of nickel, 1,452 deg. C., there was no difficulty in dissolving nickel in molten copper or bronze at much lower temperatures.

Manganese was found to be of advantage in producing considerable tenacity when added in association with small percentages of copper up to 4 or 5 per cent. The manganese itself should not exceed 1½ to 2 per cent. The compound Al Mn_4 readily formed, and being very hard and brittle rendered higher proportions of manganese detrimental to the strength of the alloy. The alloys with manganese gave favourable results in chill castings, but did not lend themselves to work such as rolling and drawing. Small quantities of manganese, 0.2 to 0.4 per cent., had been found in the alloys of which the angle and channel sections used in Zeppelin airship construction had been made. Duralumin also contained a trace of manganese.

Magnesium had been much advocated as a means of producing a strong, light alloy of aluminium. Its very low specific gravity, 1.75, much lower even than that of aluminium, enabled it to be added in any desired proportion with increased lightness in the resultant alloy. The series of alloys known as magnalium containing up to 10 per cent. magnesium or more were now fairly well known. The strength with 10 per cent. Mg. was approximately 10½ tons per sq. in. in a sand casting, 15 tons in a chill casting, and 27 tons when water-quenched.

Duralumin contained from 0.5 to 0.75 per cent. magnesium. Unfortunately, magnesium at the present time was rather difficult to obtain as well as being very expensive. It was said that magnesium alloys were very easy to machine, and that the saving in wear on cutting tools was noticeable.

Aluminium Alloys in Pistons.

The lecturer, in conclusion, dealt with recent developments in the application of aluminium alloys to the manufacture of pistons.

Previous to the war, he said, aluminium alloys had already been recognised, on account of their lightness, as having great possibilities for use in the reciprocating parts of engines. By a small reduction in weight of such parts, a large amount of energy might be saved, resulting in much greater efficiency in the engine. Even at that time pistons had already been fitted in American and French engines of one or two different makes for two or three years, and a variety of aluminium alloys had been tried for the purpose. During the war, however, a tremendous production of aeroplane engines gave an enormous impetus to research in this direction in England as well as in other countries, with the result that aluminium pistons had been standardised in nearly all aeroplane engines, and as a consequence were being quite widely adopted for use in motor-car engines.

The conditions under which pistons worked, the lecturer said, submitted aluminium alloys to tests which were quite out of the ordinary, and the success with which the metal has been adopted for this purpose, augured a very much wider field for the use of aluminium alloys in general engineering than had as yet been appreciated.

In the first place, the very considerable heat generated in petrol engines meant that the pistons and the aluminium alloys of which they were composed, must be capable of working for long periods at these high temperatures without deterioration, either from disintegration or other causes. This high temperature of itself introduced another difficulty, when the high expansion of aluminium and its alloys under the influence of heat was considered. It had, however, been found possible, by providing sufficient clearance, as well as by annealing the castings beforehand: (1) to provide room for the expansion, and (2) to somewhat reduce its extent. There were two kinds of expansion which had to be dealt with; first, the normal expansion under the influence of heat temporarily applied, and second, the permanent growth which took place under the influence of heat more continuously applied, and it was the latter species of expansion which might be reduced in the engine by previous annealing, the growth taking place during the annealing instead.

The amount of clearance between the machined piston and the bore of the cylinder should be arrived at by experiment and experience. The design of engines, varying considerably, also caused variations in the amount of heat generated, and in the capacity of the various parts of the cylinder and piston to conduct away the heat so generated.

Reference had been made to the reduction in weight effected, but there were also advantages accruing from the high heat conductivity of aluminium and its alloys, which was very much superior to cast iron or steel. The results of this quality in the metal were:—(1) That the disadvantages of the generation of excess heat in the combustion chamber when iron or steel pistons were used tended to be eliminated, as the piston itself, by conducting away a larger proportion of the heat generated reduced the evil effects. (2) By this very fact it was rendered possible to increase the compression in the combustion chamber, which hitherto had not been possible owing to the extra heat generated. The result was an increase in power in the engine. (3) The resultant advantage

was the decrease in the amount of the deposit of soot on the crown of the piston, and in the other parts of the combustion chamber, thereby reducing the choking of the passages and the risks of pre-ignition.

The thermal conductivity of aluminium, continued the speaker, was 31.3, whereas that of iron was only 11, or a little more than one-third. The thermal conductivity of aluminium was only exceeded by copper so far as the baser metals were concerned.

It would be quite clear from the foregoing that aluminium pistons, when adopted, must be specially designed, and consequently, of course, the design of the engine must, in many cases, be varied to suit them.

With regard to the alloy which should be used for the manufacture of piston castings, there was still a considerable divergence of opinion, but, speaking generally, the alloys of aluminium with copper had been very widely adopted, sometimes with the addition of a small percentage of tin, whereas the alloys of aluminium with zinc had been avoided, as they had been found to be unstable under the influence of heat. Very extensive experiments had been conducted with copper alloys, to ascertain exactly what effect the high temperatures attained under the working conditions in a petrol engine actually had upon the structure of the alloys, and upon its physical properties. An alloy containing copper and a small percentage of manganese was at one time thought to be a very suitable alloy, as it was found that its tensile strength increased with a rising temperature up to about 250 deg. C., and it was not until higher temperatures were reached that this tensile strength fell off in the normal manner. It was found, however, that the introduction of manganese reduced the thermal conductivity of the alloy, as well as introduced some difficulty in the production of sound castings, and this alloy was consequently abandoned.

The alloys very frequently used for pistons at the present time are :—Air Board Specification L 8, containing 88 per cent. aluminium and 12 per cent. copper, and Air Board Specification 2.L. 11, containing 7 per cent. copper and 1 per cent. tin. A third alloy not so frequently used is Air Board Specification L 10, containing 10 per cent. copper and 1 per cent. tin. The 10 per cent. and 12 per cent. copper alloys will give approximately 9 tons per sq. in. tensile strength, and the 7 per cent. copper-alloy approximately 8 tons per sq. in.

Discussion.

THE PRESIDENT asked which of the alloys of aluminium was most suitable for casting in chills. With regard to melting, he quite agreed that in a large pot of aluminium-zinc alloy there was a real danger of the metal segregating. That was his own experience. The metal must be stirred right up to the last moment, and not more than a minute should intervene between the stirring and the pouring. Otherwise, as Mr. Hill pointed out, the last metal to come out would be over-rich in zinc. There was a recent development in the melting of aluminium and its alloys which appeared to show great possibilities. Many years ago he made inquiries as to the melting of aluminium alloys in the electric furnace from a gentleman who was lecturing on the electric furnace in Birmingham. His (the speaker's) idea was that in a closed vessel a very high temperature would not injure the metal, that one might melt aluminium very quickly as in the electric furnace, without injuring it, provided no injurious gases were allowed to impinge upon the metal. He believed that an electric furnace had been designed in America for melting aluminium and had been used by manufacturers there with considerable success. It was an arc furnace, the electrodes being connected up with the resisting composition of the furnace and the metal being melted by radiated heat. That type of furnace, it seemed to him, would supersede all other types if the cost of current could be kept within reasonable limits. With regard to Mr. Hill's repeated caution as to avoiding excessive heat in the furnace, he would like to ask whether excessive heat in a metal which was afterwards poured at the right temperature had caused defects, and, if so, what those defects were? His own experience was that a considerable excess of temperature in melting did not cause any serious trouble if the pouring temperature was right. In the early days of the aluminium founding industry makers were pestered with small pin-holes, and these were regularly attributed to overheating. A few years ago Mr. Hurren gave a Paper in Birmingham in which he completely confuted that theory and maintained that the metal might safely be overheated if no injurious gas was allowed to act upon it. It was, however, agreed that the pouring temperatures must be carefully regulated. His own experience confirmed Mr. Hill's that the pin-holes in castings of that type were due to another cause altogether.

The discussion was continued by Mr. Drake, who expressed doubt as to the success of melting in gas furnaces without crucibles.

MR. HILL, dealing first with Mr. Harley's question as to aluminium alloys suited for die-casting, said that he regarded that as a separate subject, and therefore had not included any information with regard to it. He might, however, express the opinion that no particular alloy could be regarded as suitable for all die-castings; a great deal depended, of course, as in sand-castings, on the purpose to which the castings were to be applied, and to the nature of their design. Several of the alloys which he had described as suitable for sand-castings were equally suitable for die-castings. Provided an alloy were not used which would be likely to be detrimental to the surface of the dies, no serious difficulty ought to be occasioned in finding good workable alloys, most of the copper alloys serving the purpose admirably. In producing successful die-castings, it was probably necessary to acquire more skill and experience in the construction and use of the dies, and in the pouring of the die-castings, than was necessary in the selection of the particular alloy to be used, although discretion and experience were necessary with regard to this also.

Regarding furnaces used for melting aluminium, his experience in the use of furnaces consuming oil as a fuel was very limited, but from his considerable experience in the use of coke and gas as a fuel in furnaces for this purpose, he had no hesitation in strongly advocating gas furnaces as not only the more economical, but also the more useful of the two. In the first place, gas furnaces were more efficient. For a given expenditure it was possible to melt the metal at a lower cost per ton melted and in less time, and in the second place, even supposing the gain in efficiency to be slight, which indeed it was not, the great gain in convenience would well justify the selection of the gas furnace in preference to the coke furnace.

The coke must be handled at the railway sidings, in the foundry yard, at the furnaces, and, subsequently, the residue must be handled again in the form of ashes at the furnace, in the foundry yard and at the tip. Further, any metal spilt at the furnaces became mixed with the ashes, and considerable labour and expense was involved in separating it. When gas was used, the gas was delivered right into the furnace through a pipe; there were no ashes, the products of combustion went up the chimney, and any metal spilt did not become mixed with any foreign matters. Consequently, the saving in labour was enormous, and clean working was obtained. He was very interested in Mr. Harley's remarks to the effect that no injury was caused to the aluminium or its alloys if they were overheated in the furnace, provided that the overheating did not take place in the presence of the atmosphere, and provided also that the casting was subsequently poured at the correct temperature, and that, given these conditions, no matter how hot the metal was in the furnace, if it was cooled down to the correct pouring temperature, the casting would give the necessary results. He could not quarrel with this statement, which he believed to be, so far as our present knowledge went, scientifically accurate. But under working conditions it was not possible entirely to exclude the atmosphere from the metal when being melted in the furnace. He sincerely hoped that if any furnacemen were present, they would not take the statement as authority for overheating the metal, as he was convinced that the results would be disastrous. In his experience, these results consisted in the formation of oxides which were probably excluded from the crystal during the early stages of solidification of the alloy, and being thus segregated in the inter-crystalline spaces, caused weakness, resulting in the formation of cracks, which followed clearly those inter-crystalline spaces. For safe working, therefore, he strongly advocated, as stated in his Paper, that the metal be not raised above a temperature of 720 deg. C. in the furnace. This temperature should be sufficient to enable castings of all natures and designs to be successfully poured.

In reply to Mr. Drake, who suggested that the melting of aluminium alloys in gas furnaces without crucibles, so that the gas flames played upon the metal, might cause oxidation of the metal during melting, he would point out that, in the first place, in the furnaces described in the Paper very special precautions were taken to control the supply of air to the furnaces, so that no more air was admitted than was required to consume the gas completely during combustion. The result was that there was always a reducing atmosphere inside the furnace and not an oxidising one. He must, however, admit that, owing to the necessity of opening and closing the charging doors, a certain amount of air was occasionally admitted; but the temporary evil influence of this additional air was not found in practice to be detrimental, provided the temperature of the metal was not allowed to rise above the temperatures indicated.

Palmers Shipbuilding & Iron Company, Limited, are erecting an extensive boiler shop at their Jarrow Works.

Barimar, Limited, of 10, Poland Street, London, W.1, announce the completion of arrangements for the opening of new branches at Calcutta, Delhi, Bombay, Madras, Karachi, Burma, and Ceylon.

An Improved Rapid-Melting Cupolette.

The Constructional Engineering Company, Titan Works, Birmingham, have designed an improved form of cupolette for emergency work, special mixtures and general experiments and instructional purposes. The furnace has been designed to meet the demand for a small self-contained plant, and it has been found of considerable value in small engineering and repair shops.

Several of these furnaces were used on the Western Front in the motor repair shops, and they have also been mounted on a tramcar chassis for use in melting metal *in situ* for casting joints of tram rails.

The results of melting tests average 3 cwt. of coke per ton of metal melted. In the No. 3 size 7 cwt. of metal can be melted in 15 minutes from turning on the blast. To facilitate relieving, the cupolette is made to tilt in the horizontal position, and stays for supporting are fitted.

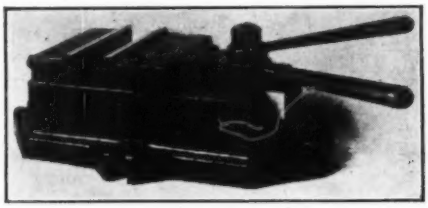
The furnace is fitted with drop-bottom, special tyeres sight holes, fettling door, tapping and slagging spouts, and is supplied complete with motor or belt-driven fan.

Bolckow, Vaughan & Company, Limited, have acquired a controlling interest in the Darlington Rolling Mills Company, Limited, hitherto under the sole control of Mr. G. E. Sisterson. This will entail an increase and rearrangement of the capital of the Darlington Rolling Mills and of the board. Mr. G. Sisterson will, however, remain chairman and managing director of the company, so that continuity of management is secured.

The Hartford Quick-Acting Vice.

The vice shown in our illustration has been specially designed to retain its accuracy and firm grip under long-continued heavy service. Large numbers of them have been used, we are told, by one of the largest makers of fire-arms in the U.S.A. with exceptional success.

The action is the reverse of that commonly made use of on machine vices. The jaw on the left of the illustration is a fixture, while the jaw on the right is drawn towards it. There is no screw or nut to wear out and require replacement. The two handles are pivoted on a bolt, which has a square head sliding in a T slot, and is clamped in position in the slot by a nut, while the handles are both free to turn. All



possibility of the bolt moving endwise, when clamped, is obviated by a serrated washer which engages the serrations on the moving member of the vice.

When it is required to hold anything in the vice, the jaws are first set to the proximate size, and the nut on the square-head bolt tightened. The jaw is then brought into contact with the work by the cam on the end of the lower handle. The upper handle, which is set slightly eccentric to the lower, is then turned. The great leverage thereby gained draws the jaw up to the work with great force.

Two styles of vice are made; one, as illustrated, with plain jaw, and one with swivel jaw. The opening of the swivel jaw vice is 1 15-16 in. when hard jaw faces are in use, or 2 3-16 in. with soft jaws. These jaws can be milled for holding two pieces at once.

Messrs. Alfred Herbert, Limited, Coventry, are the sole distributors of these vices in Great Britain and other countries.

MOLYBDENUM STEEL. — We learn from the "Times Engineering Supplement" that Dr. Arnold has sold his production rights to Mr. J. D. Moffat, one of the directors of Sir Thomas Salter Pyne & Company, and that the new steel is to be made in Sheffield. Mr. Moffat is losing no time in completing his arrangements for putting the steel on the market at the earliest date possible, and has arranged to acquire the controlling interest in a Sheffield firm. There is naturally some difference of opinion as to the value of the new steel. It is pointed out that the supply of tungsten is not so good as it was, and the supply is by no means inexhaustible. In Dr. Arnold's process molybdenum, with a small percentage of vanadium, forms the chief constituent. Even if tungsten were available in greater quantities some people think that the new compound would show superior wear-resisting qualities. When tungsten is employed from 18 to 22 per cent. of it is necessary, whereas only 6 per cent. of molybdenum is required. It is said that there are large supplies of the latter element available, and there is also a prospect of cheapening its production by a new method which is to be used at the Sheffield works, and which it is claimed it will be able to produce in the state necessary for its use in making the new steel at a cost half that of tungsten. Tungsten steel has, however, its strong advocates, and the rivalry between the two will be watched with considerable interest in Sheffield.

Trade Talk.

THE CORNHILL ENGINEERING COMPANY, LIMITED, will in future be known as Henry Wilson & Company (1920), Limited.

MESSRS. LEWIS LAZARUS & SONS, metal merchants, Lime Street, E.C.3, have established a branch at 1,503, Royal Bank Buildings, Toronto.

MESSRS. DOLBY & WILLIAMSON, consulting engineers, have now returned to their offices at 8, Princes Street, Westminster, S.W.1, the Government having vacated the premises.

THE ELECTRIC CONSTRUCTION COMPANY, LIMITED, of Wolverhampton, have appointed Mr. R. Millett as their sole Lancashire and Yorkshire agent, with offices at 30, Cross Street, Manchester.

THE METROPOLITAN-VICKERS ELECTRICAL COMPANY, LIMITED, have removed their London office from 2, Norfolk Street, Strand, London, W.C., to 4, Central Buildings, Westminster, London, S.W.1.

JOHN THOMPSON (WOLVERHAMPTON), LIMITED, have purchased the goodwill, books, drawings, and most of machinery (including special flanging press, etc.), of Fred Danks, Limited, Oldbury, Staffs.

IT is reported that Guest, Keen & Nettlefolds, Limited, in conjunction with a Paris firm, have acquired control of the two largest Austrian screw-making concerns—those of Brevillier & Company and A Urban & Sons.

THE United States Bureau of Mines has recently issued a Technical Paper, 241, entitled "Blow-holes, Porosity, and Unsoundness in Aluminium Alloy Castings." The author is Robert J. Anderson, of the Bureau's branch at Pittsburgh. The paper discusses the magnitude of the light alloy industry; gases in aluminium; solidification of metals; analogy with steel; effects of various processes in casting, melting, moulding, etc., as well as the metallography and radiography of the subject

STEWARTS & LLOYDS, LIMITED, of Glasgow, have arranged that any of their employés who join a Territorial unit and attend camp shall have their military pay and allowances while in camp made up to their civil rate of pay, with a maximum of £5 per week. The civil pay will be taken at the rate earned during the last full fortnight before camp, and the necessary adjustment will be made by the firm on production by each man of a certificate by his commanding officer of the period during which the man was in camp and the amount of his Army pay and allowances.

THE TWISS ENGINEERING & ELECTRIC TRANSMISSION, LIMITED, have acquired the transmission line contracting department of J. B. Saunders & Company, Limited, which will become incorporated in the company's organisation, together with the services of Mr. S. G. Leech as the director of contracts. The Twiss Engineering & Electric Transmission, Limited, are also expanding their works at Mildmay Park, and laying down new plant to facilitate the manufacture of transmission line material. In future the name of the company will be Twiss Electric Transmission, Limited.

THE employés of W. Gray & Company, Limited, at their West Hartlepool shipyards and engine works, have held a meeting for the purpose of expressing their gratitude for the financial benefits they have received through Sir Wm. Gray's profit-sharing scheme, under which a sum of over £55,000 has just been distributed amongst employés who had not lost more than nine days' working time during the nine months the scheme has been in operation. Mr. D. Ward presided at the meeting, and Mr. Sargeant, in moving the vote of appreciation, expressed the hope that the Shipbuilding Employers' Federation would copy the example of Messrs. William Gray and Company.

SAND GLASS & FOUNDRY MATERIALS (AMALGAMATED), LIMITED, have been formed to acquire a group of mineral deposits which belong with one exception to

MOULDING MACHINES

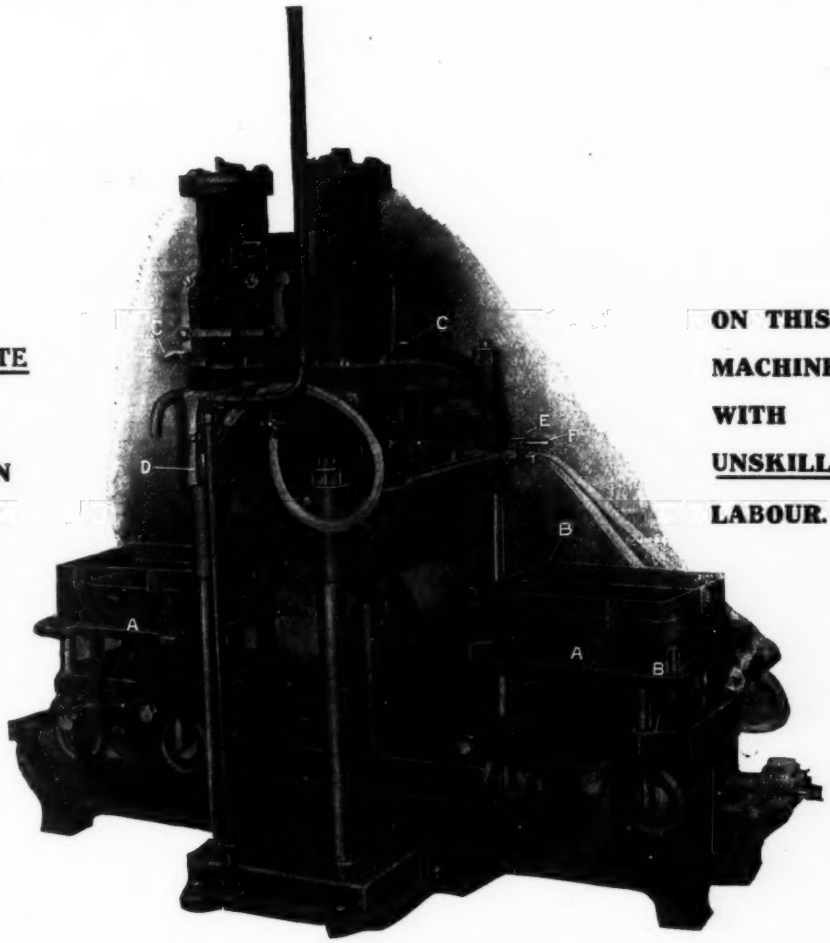
OF EVERY DESCRIPTION.

Pneumatic, Hydraulic, Jar Ramming, & Hand Power.

Type "A" Duplex Machine for Pneumatic Power.

Fitted with self-adjusting Rammer Head which accommodates itself to any varying depth of pattern.

OVER 50 COMPLETE MOULDS PER HOUR HAVE BEEN PRODUCED



ON THIS MACHINE WITH UNSKILLED LABOUR.

One of many that we have installed in various Munition Work Centres.

JAMES EVANS & CO., BRITANNIA WORKS, BLACKFRIARS, MANCHESTER.

existing companies and are mainly situated in South Yorkshire. The various undertakings are the High Silica Sands Company, T. H. Lyon and Partner, the Doncaster Sand & Gravel Company, the Barnby Dun Sand & Gravel Company, F. G. Foster & Company, Lockwood Blagden & Crawshaw, the Yorkshire Refractories Company, and Walker & Crawshaw. The capital is £300,000 in ordinary £1 shares, 100,000 shares being allotted in part payment of the purchase price. The remaining 200,000 have been offered to the public.

THE directors of the Ebbw Vale Steel, Iron and Coal Company, Limited, announce that last year, notwithstanding the strikes, wages paid amounted to £3,119,528, as compared with £2,565,725 during the previous year. The development of the iron ore undertakings in Northamptonshire has continued to make excellent progress, whilst the extensions at the iron and steel works at Ebbw Vale and Newport, notwithstanding the delays which were inevitably occasioned by internal and external strikes, are approaching completion. The production during the year was:—Coal, 1,582,143 tons; coke, 138,508 tons; pig-iron, 96,128 tons; and steel, 79,607 tons; a total decrease of 404,176 tons, as compared with the previous twelve months.

THE Secretary of the Department of Scientific and Industrial Research begs to announce that the Research Association for the British Motor Cycle and Cycle Car Industry has been approved by the Department as complying with the conditions laid down in the Government scheme for the encouragement of industrial research. As the Association is to be registered as a non-profit sharing company, the promoters have applied to the Board of Trade for the issue of a licence under Section 20 of the Companies' (Consolidation) Act of 1908. The Secretary of the Committee engaged in the establishment of this Association is Major H. R. Watling, "The Towers," Warwick Road, Coventry.

DURING the past year an entire change has taken place in the business of Callender's Cable and Construction Company, Limited, as the factories both at Erith and of the Anchor Company at Leigh have been converted from manufacturing war materials to ordinary commercial production. Output was seriously interfered with, but the change-over is now complete, with most satisfactory results. In the early part of the year it became evident that additional plant and machinery were required to meet the increasing demands of the industry for cables capable of working at much higher voltages than in the past. Extensive new workshops were therefore erected for the manufacture of super-tension mains of 33,000 volts and upwards, and these are now practically completed. The Picardy works, which were specially erected and equipped with machinery for the rapid manufacture of field telephone cables for the Army, have been completely converted and re-equipped with plant for the manufacture of telephone cables for general use.

THE PRESIDENT OF THE BOARD OF TRADE (Sir Robert Horne) recently received a deputation representing the Joint Industrial Council for the Tin-Mining Industry of the United Kingdom. The deputation was introduced by Mr. H. D. Betterton, M.P., and Mr. Harris, the chairman of the Industrial Council, presented a statement, pointing out that financial assistance was urgently required to enable the Cornish mines to carry on development work, without which two of the important mines, which had already given notice to their workmen, would have to close. It was suggested that the Development Commission should be asked to make a grant of £200,000 to the Industrial Council, to be expended on development work in the next two years, the money to be repaid out of the profits arising from the developments. Other speakers emphasised the distress that would ensue among the mining community of Cornwall if the mines were compelled to close. Sir Robert Horne, in reply, said he would consider the whole position at once with the greatest care in order to ascertain if the points which had been raised by the deputation could be met.

THE lead and zinc mining industry is in a fairly active condition. A number of firms are buying galena for the purpose of producing pigments, and there is a certain amount of business for the export of first-grade concentrates. The precarious condition of the zinc smelting industry has had an adverse effect upon the mining of zinc ores, but an outlet for blende has been found amongst firms who are producing zinc compounds, and these users should be able to absorb any output that is likely to be raised during the next few years. The mines at Nenthead are still standing but the Vieille Montagne Zinc Company is opening out Nentsbury Mine that has recently been acquired, and a small number of men are engaged there. The Threlkeld Mine is gradually improving in its position, and is now turning out weekly about eleven tons of lead and zinc concentrates. Thornthwaite Mine is considerably increasing its output. Greenside Mine, in Patterdale, is producing large quantities of lead ore, but has temporarily abandoned smelting. A certain amount of exploration is being carried out in the Newlands Valley and in the neighbourhood of Threlkeld. A small company is being formed to explore thoroughly the Caldbeck area with a view to proving the existence of payable mineral bodies.

Personal.

THE late Mr. H. McGarter Joel, steel and file manufacturer, Sheffield, left £61,405.

SIR REGINALD H. BRADE has been elected a director of the Austin Motor Company, Limited.

THE late Mr. C. Chittick, of M. T. Shaw & Company, Limited, engineers, Millwall, left £44,779 gross.

THE late Mr. F. E. Collier, of Messrs. Collier Bros., Albert Square, Manchester, metal merchants, left £13,221.

THE gross value of the estate of the late Mr. R. E. Ormsby, of Newcastle-upon-Tyne, mining engineer, is £29,484.

MR. CARGILL has been elected an additional director of the Anderston Foundry Company, Limited.

THE late Mr. H. Cumberland, a director of Sutton & Ash, Limited, iron merchants, etc., of Birmingham, left £13,092.

THE late Mr. Jameson, a director of Reay & Usher, Limited, South Hylton Ironworks, Hylton, Co. Durham, left £8,835.

MR. W. L. HICHENS, chairman of Cammell, Laird & Company, Limited, is mentioned as a probable member of the Imperial Shipping Committee.

THE late Mr. A. Izat, a director of the Bengal Iron & Steel Company, Limited, left, in addition to real estate, personal estate of the total value of £160,941, of which the personal estate in the U.K. amounts to £144,619.

COL. SIR JOHN ROGER WRIGHT, BART., chairman of Baldwin's, Limited, has been the recipient of a handsome presentation in commemoration of the honour of baronetcy conferred upon him last year in recognition of distinguished services.

MR. C. SMITH, of Newcastle, has been elected chairman of the directorate of the Consett Iron Company, Limited, in succession to Mr. M. Fenwick. Mr. Smith is a director of Smith's Dock Company, Limited, and also managing director of the firm of T. & W. Smith, Limited, of Newcastle, wire rope manufacturers.

MR. R. S. JOHNSON, for many years connected with the firm of Workman, Clark & Company, Limited, has joined the board of Cammell, Laird & Company, Limited, and will assist Sir G. J. Carter at the Birkenhead works. Mr. J. M. Ormston, who has been assistant manager of the Birkenhead shipyard for some time past, has been appointed shipyard manager at Birkenhead in the place of Mr. Havish, who recently resigned.

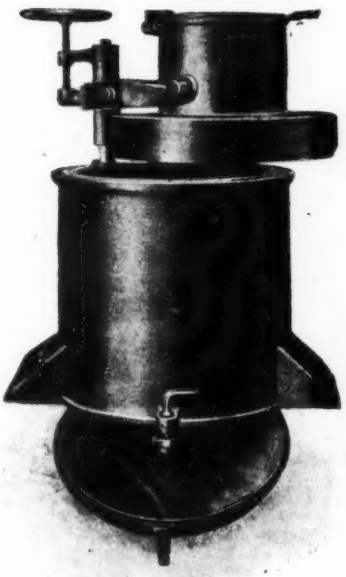
THE King has given orders for the following appoint-

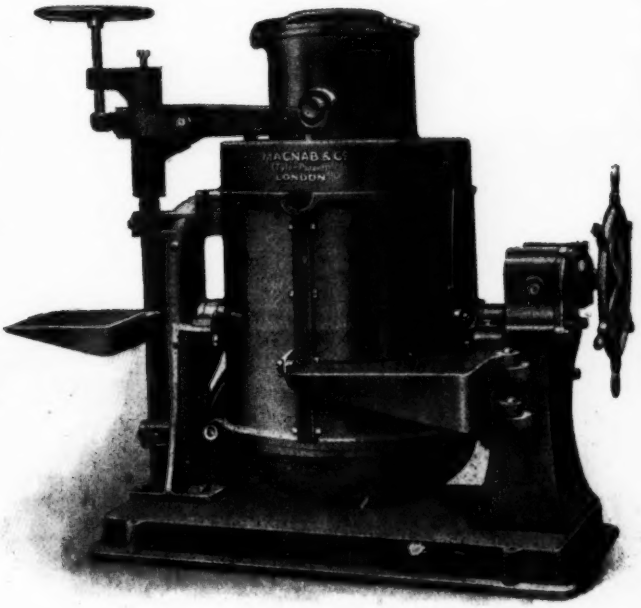
MACNAB & CO.

METAL MELTING CRUCIBLE FURNACE

For Brass, Gunmetal, Aluminium, Iron, etc.

Reduce your fuel cost! **Melt in a hurry!**





Tylor Patent Pit-Type Furnace.

OUTPUT.
200 lbs. Admiralty Gunmetal melted in 35 minutes. Temperature 2000° F.=1093° C.

ECONOMY.
25 lbs. of Coke used per 200 lbs. of Metal melted.

STANDARD CRUCIBLES.
Lasting 35 to 40 heats.

Tylor Patent Tilting-Type Furnace.

OUTPUT.
400 lbs. Admiralty Gunmetal melted in 50 minutes. Temperature 2000° F.=1093° C.

ECONOMY.
80 lbs. of Coke used per 450 lbs. of Metal melted.

STANDARD CRUCIBLES.
Lasting 30 to 40 heats.

56/8, EAGLE STREET, SOUTHAMPTON ROW, LONDON, W.C.1.

Works: TOTTENHAM, LONDON, N.17.

ments to the Most Excellent Order of the British Empire (Civil Division) for services in connection with the War, to be dated January 1, 1920:—Commanders (C.B.E.).—Mr. T. B. Barker, Deputy Director of Raw Materials, War Office. Officers (O.B.E.).—Mr. C. M. Hunter, Section Director, Railway Materials Department, Ministry of Munitions; Mr. F. T. Small, Technical Personal Assistant to Controller of Supply Department, Ministry of Munitions. Members (M.B.E.).—Mr. R. J. Craig, Manager at H.M. Factory, Avonmouth, Ministry of Munitions; Mr. E. P. Evans, Late Administrative Assistant, Department of Controller-General of Merchant Shipbuilding, Ministry of Shipping; Mr. G. D'O. Gowan, Manager, George Kent, Limited; Mr. E. B. Irwin, Technical Assistant, Department of Controller-General of Merchant Shipbuilding, Ministry of Shipping.

Deaths.

THE death is reported of Mr. J. W. Lowe, furnace manager to the Parkgate Iron & Steel Company, Limited, at the age of 44 years.

MR. E. R. SHELDON died suddenly at his residence at Chatsworth Square, Carlisle, on June 4. The deceased gentleman was connected with the engineering firm of Cowans, Sheldon & Company, Limited, Carlisle.

MR. J. G. SCOTT, engineer, who has died at his residence at Jarrow, at the age of 60 years, was the inventor of several approved appliances for boilers, etc., and about 20 years ago he began the manufacture of his own patents, continuing in business up to the time of his death.

MR. F. BOWES, managing director of Richard Hill & Company, Limited, Marsh Wire Works, Middlesbrough, died at his residence, Woodlands Lodge, Middlesbrough, on June 3, after a brief illness. Mr Bowes, who was born at Stockton 70 years ago, was for many years secretary to Messrs. Richard Hill & Company. Later he became general manager, and in 1910 was elected managing director.

SIR FRANK MAPPIN, second baronet, of Birchlands, Fulwood Road, Sheffield, died on May 30 after a short illness. The deceased was the eldest son of Sir Frederick Mappin, and was born on September 6, 1846. He succeeded in 1910 to the baronetcy which was conferred on his father in 1886. His business life was spent at the works of Thomas Turton & Sons, Limited, steel and file manufacturers, Sheaf Works, Sheffield, with which his father was connected before him. Sir Frank was managing director of the firm for many years, and devoted himself assiduously to its business. For several years a member of the Cutlers' Company, he became Junior Warden in 1886, retiring the following year.

New Companies.

Glyn Engineering Works, Limited.—Capital £20,000 in £10 shares.

Derbyshire Basic Company, Limited. — Capital £75,000 in £1 shares.

Liverpool Mineral & Metal Storage Company, Limited.—Capital £50,000 in £1 shares.

Bolton Crucible Steel Company, Limited. — Capital £12,000 in £1 shares. Registered office: Bella Street, Bolton.

Uno Company, Limited, Engineers.—Capital £5,000 in £1 shares. Registered office: 90, Minories, Tower Hill, E.

Selga Engineering Company, Limited. — Capital £1,000 in £1 shares. Registered office: 46, Whitefriars Street, Coventry.

Arbroath Foundry Company, Limited. — Capital £7,000 in £1 shares. Registered office: 6, East Neavy Street, Arbroath.

Neilson Welch & Company, Limited, Engineers.—Capital £6,000 in £1 shares. Registered office: Buckingham Gate, S.W.

Plank Lane Foundry Company, Limited. — Capital £5,000 in £5 shares. Registered office: Plank Lane. Foundry, Leigh, Lancs.

Triplex Foundry, Limited.—Capital £10,000 in £1 shares, to take over the business of the Triplex Grate Company, Great Bridge.

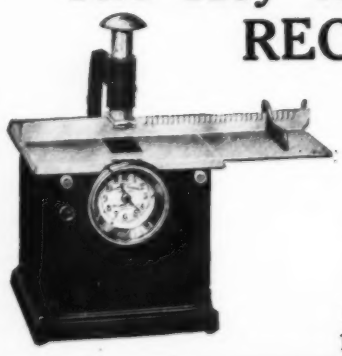
Kilmarnock Brass Foundry Company, Limited. — Capital £1,000 in £1 shares. Registered office: 37, Bank Street, Kilmarnock.

H. A. Bryce, Limited.—Capital £5,000 in £1 shares, to carry on the business of engineers. Registered office: 69, Middlewood Road, Hillsbrough, Sheffield.

Glew & Company, Limited.—Capital £20.000 in £1

BLICK TIME RECORDERS

The Key to RECONSTRUCTION



Every minute in the largest Works and the smallest Factory must be guarded if the problem of increased production is to be solved. The Blick system of time recording ensures this. Simple and efficient to the highest point, the day, hour and EXACT MINUTE are registered when employees enter and leave. Modern card methods. Racks for any number of Workmen.

Write for Booklet "22." It tells you quite a lot about the organisation of Works.

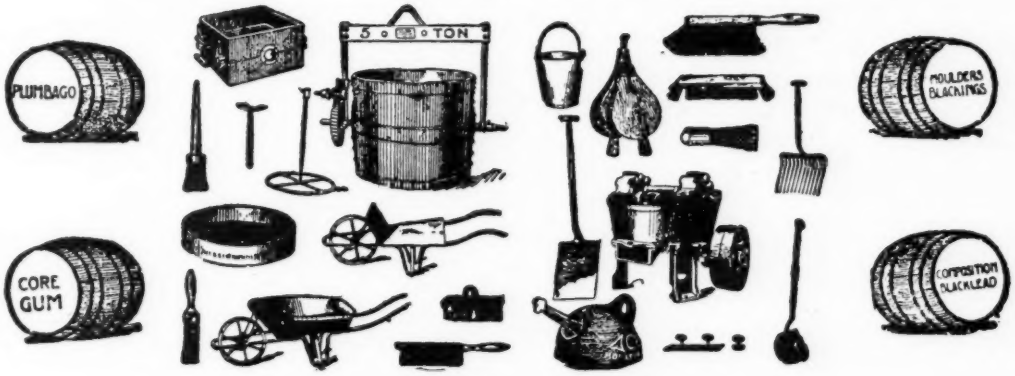
BLICK TIME RECORDING DEVICES,
174, Gray's Inn Road, LONDON, W.C.

Telephone: 21, Pennistone. Telegrams: "Durrans, Pennistone."

Established 1863.

JAS. DURRANS & SONS,

Phœnix Works, Penistone, Near Sheffield.



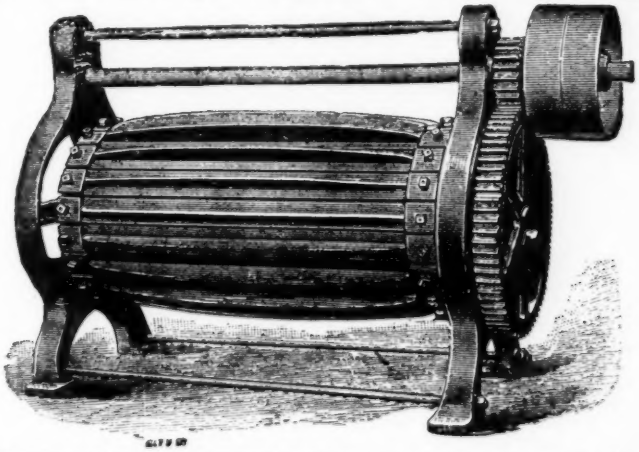
Manufacturers of all

FOUNDRY EQUIPMENTS

COMPOSITION BLACK LEAD, PLUMBAGO, CORE GUM, WHITE DUST & COAL DUST

Ladles, Cupolas, Fire Bricks, Gannister, Stone Flux, Loam and Sand Mills, Casting Cleaners, Studs, Chaplets, Pipe Nails, Sprigs, Brushes, Wire Brushes, Core Ropes, Bellows, Buckets, Spades, Forks, Riddles, Sieves, Barrows, Etc.

Improved Foundry Rattler or Fettling Drum.



These Machines are invaluable for a Foundry, doing a larger amount of work of a superior quality, in a much shorter time than can be done by hand, without skilled labour.

The following testimonial explains itself :—

"Dear Sirs,—We have been using your best Blacking for a large number of years, and always use it on our large Ingot Moulds, which, as you know, we have made up to 85 tons in weight.

Yours faithfully, THE BRIGHTSIDE FOUNDRY & ENGINEERING CO., LD.

shares, to carry on the business of wire drawers, etc., and to adopt an agreement with J. W. Glew.

Orton & Company, Limited.—Capital £8,000 in £1 shares, to carry on the business of engineers. Registered office: Lawrence Street, Mill Hill, N.W.

Quinton, Arthur & Company, Limited, Hardware Merchants.—Capital £5,000 in £1 shares. Registered office: 4, Pool Square, Barkers Pool, Sheffield.

E. W. Sweet & Company, Limited.—Capital £7,000 in £1 shares, to carry on the business of engineers. Registered office: Shannons Hill, Fishponds, Bristol.

Hays, Standen & Company, Limited. — Capital £50,000 in £1 shares, to carry on the business of engineers. Registered office: 71, Southwark Street, S.E.

William Platts & Company, Limited. — Capital £100,000, to acquire the business of shipbuilders and engineers carried on at Whitehall Shipyard, Whitby.

Winser's (Tunbridge Wells), Limited. — Capital £20,000 in £1 shares, to carry on the business of engineers. Registered office: 49, Finsbury Pavement, E.C.

City Electric Welding Company (Newcastle), Limited.—Capital £5,000 in £1 shares. Registered offices: 2 and 4, Stephen Street, Bridge End, Byker, Newcastle-on-Tyne.

Galpin Hall & Company, Limited.—Capital £6,000 in £1 shares, to carry on the business of engineers. Registered office: 200, High Street, Scunthorpe, and Frodingham, Lincs.

James, Talbot & Davison (1920), Limited.—Capital £150,000 in £1 (50,000 eight per cent. cumulative part preference) shares, to carry on the business of engineers. Registered office: Waveney Works, Lowestoft.

Robert Jenkins & Company, Limited. — Capital £34,600, to carry on the business of engineers, at Rotherham. Directors: A. T. Jenkins, E. J. Jenkins, H. C. Jenkins, and R. W. Jenkins.

B. Young & Company (Birmingham), Limited. — Capital £3,000 in £1 shares, to carry on the business of electrical and mechanical engineers, etc. Registered office: 100, Leek Street, Birmingham.

William Asquith (1920), Limited.—Capital £600,000 in £1 shares (300,000 8 per cent. cumulative participating preference), to carry on the business of machine tool manufacturers. Registered office: Highroad Well Works, Halifax.

Palmer & Young, Limited.—Capital £2,000 in £1 shares (500 cumulative preference), to carry on the business of manufacturers of castings, etc. J. A. Potter is first director. Registered office: 636, Attercliffe Road, Sheffield.

Robert Duncan (Partick Foundry), Limited.—Capital £30,000 in 10,000 preference and 20,000 ordinary shares of £1 each, to acquire the business carried on at the Partick Foundry. Registered office: South Orchard Street, Partick, Glasgow.

Scottish Steel Barrel Company, Limited. — Capital £10,000 in 8,800 preference shares of £1 and 24,000 ordinary shares of 1s. each, to acquire the business of Wm. Clark & Son, John Street, Glasgow. Registered office: 197, Rotten Row, Glasgow.

William Bayliss, Limited.—Capital £100,000 in £1 shares, to take over the brass, copper, and cased-tube department of the business of William Baylis, Limited, now carried on at Sheepcote Street, Birmingham. First directors: E. J. Smith, C. H. Ryland, A. D. Keeling, A. Wright, and W. J. Gold. Registered office: Islington Tube Works, Sheepcote Street, Birmingham.

Michell Bearings, Limited.—Capital £100,000 in £1 shares, to adopt an agreement with A. G. M. Michell and H. T. Newbigin. Each of the following may appoint one director, viz.: Vickers, Limited; Cammell, Laird & Company, Limited; John Brown & Company, Limited; the Fairfield Shipbuilding & Engineering Company, Limited; A. G. M. Michell, and H. T. Newbigin.

ATTAINED AT LAST!

The 99 % Pure Aluminium

REAL PRESSURE DIE CASTING PLANT

Pressure Die Casting in PURE ALUMINIUM can now be done just as easily as White Metal Die Casting.

The only HEAT CONTROLLED, REAL PRESSURE Die Casting Machine on the WORLD'S MARKET.

Patented in all CIVILISED COUNTRIES under Hall's Patents.

Sole Makers: MONOMETER MFG. CO. (1918) Ltd.,

Manufacturers of all types of Melting, Hardening and Annealing Furnaces.

Ladywood Foundry, Browning Street, BIRMINGHAM.

We can quote for all dies and parts for pressure die casting in White Metal and Pure luminium.

WHAT MESSRS. RANSOME & MARLES SAY ABOUT OUR WHITE METAL PRESSURE DIE-CASTING MACHINE—

"To the Monometer Manufacturing Co. (1918) Ltd.,
Browning Street, Birmingham

Dear Sirs,

We have much pleasure in informing you that we have five "Monometer" Die Casting Machines in regular use in our Works, running double shifts, and have found them most satisfactory in operation and excellently suited for producing our Cages economically in large quantities.

We have sent you, under separate cover, a few samples of the latter produced on your machines, and these bear witness to the high class of work produced.

Yours faithfully,
For Ransome & Marles Bearing Co., Ltd.,
(Signed) C. C. RICHARDS,
Assistant Works Manager."

Call and see these and other furnaces at our Stand No. 162, Engineering Section, Crystal Palace Exhibition.

WE SUPPLY **THE** LEADING FIRMS IN THE TRADE WITH

FOUNDRY BLACKINGS

OF ALL KINDS

COAL DUST, CHARCOAL, PLUMBACO and BLACK-LEAD CORE GUMS and all Foundry Requisites, and have done so since 1831.

I. & I. WALKER, EFFINGHAM MILLS, ROTHERHAM.

Our Specialite is Studying Special Requirements.

KINDLY HAND US YOUR ENQUIRIES.

The Mastery

of the Air.

SIROCCO TRADE MARK

FANS

SEND US YOUR ENQUIRIES FOR

are always successful in the struggle for the Mastery of the Air

Ventilation of Ships, Buildings and Mines, Induced Draught on Boilers, Dust Removal, High Pressure Fans for Forge Fires and Cupolas, Air Washers for Cooling and Purifying the Air, Fans for Removing Fumes or Steam, Steam Heater Units for Heating Factories and Workshops.

Davidson & Co., Limited, *Sirocco Works,* **BELFAST.**

GANISTER, CUPOLA BLOCKS, FIRE BRICKS,

FIRE CLAY.

Silica Bricks, Tuyeres, Stoppers, Nozzles, &c.

STEEL MOULDERS' COMPOSITION, SILICA CEMENT.

J. GRAYSON LOWOOD & Co., Ltd.,

DEEPCAR nr. SHEFFIELD.

Telegrams: "LOWOOD, DEEPCAR."

MONTHLY PRICE LIST.

The undermentioned prices, unless otherwise specified, are those obtaining at the commencement of the current month.

Pig-Iron.

	Home £ s. d.
Hematite—	
East Coast Mixed Nos.	13 0 0
East Coast No. 1	13 2 6
West Coast Mixed Nos.	14 15 0
Scottish Mixed Nos.	14 5 0
Welsh Mixed Nos.	14 0 0
Cleveland—	
No. 1	11 10 0
No. 3 foundry G.M.B.	10 17 6
No. 4 foundry	10 17 6
No. 4 forge	10 17 6
Basic	11 7 6
Derbyshire, Leices., and Notts—	
No. 4 forge	12 0 0
No. 3 foundry	12 5 0
No. 2 foundry	12 7 0
No. 1 foundry	12 9 0
Basic	12 5 0
Northamptonshire—	
No. 4 forge	11 10 0
No. 4 foundry	11 11 6
No. 3 foundry	11 12 6
No. 2 foundry	11 14 0
No. 1 foundry	11 15 0
Basic	12 0 0
South Staffordshire, Shropshire and Worcestershire—	
Part-mine forge	12 2 6
Part-mine foundry	12 5 0
Common Staffs.	10 15 0
All-mine forge	12 15 0
All-mine foundry	13 0 0
Warm-air forge	13 12 6
Warm-air foundry	14 2 6
Cold blast	17 0 0
Basic	12 5 0
Scottish—	
Foundry, No. 3	13 5 0
Delivered in Manchester—	
*Derbyshire, No. 3	—
*Cleveland, No. 3	—
*Scottish, No. 3	—
* Merchant prices.	
Delivered in Sheffield—	
East Coast hematite	—
Derbyshire basic	—
Lincolnshire basic	—
Do. No. 3 foundry	—
Do. forge	—

High-Speed Tool Steel.

	s. d.
Finished bars, 14 per cent. Tungsten	3 6
Finished bars, 18 per cent. Tungsten. Per lb. delivered buyers' works.	4 3
Extras—	
Rounds and squares 3 in. to 8 in. inclusive	4d. per lb.
Rounds and squares under ½ in. to ¾ in.	3d. ,,
Flats under 1 in. by ¾ in. to ½ in. by ¾ in., and all sizes over four times 3 in width and over thickness	3d. ,,
Bevels of approved sizes and sections	6d. ,,
If in Coils	3d. ,,
Packing	4s. per cwt
Bars cut to length	10% extra
Scrap from High-Speed Tool Steel—	
Scrap pieces, 5d.	
Turnings and Swarf, 3d.	
Per lb. net, d/d steel-makers' works.	

Ferro-Alloys.

Ferro-Titanium—23/25%, Ti. carbonless, 1/10.
Ferro-Tungsten.—75/80%, 3/3.
Ferro-Molybdenum.—70/80%, Mo., 10/-.
Ferro-Vanadium.—35/40%, Va., 65/-.
Metallic-Manganese.—98/99%, carbonless, 4/-. (All per lb.).
Ferro-Phosphorus—20/25%, P. £52 10 0.
Ferro-Chrome.—4/6%, car., £46 0 0.
Ferro-Chrome.—6/8%, car., £44 0 0.
Ferro-Chrome.—8/10%, car., £42 0 0.
Ferro-Chrome.—Specially refined, basis 60% chr., max. 2% car., £96 0 0.
Ferro-Silicon.—45/50% Si., £25 0 0 d/d. at Sheffield Steelworks.
Ferro-Manganese.—80%, £37; loose, £38. packed. Export £45, according to destination. (All per ton.)

Copper.

	£ s. d.	£ s. d.
Standard cash	84 15 0	85 0 0
Three months	87 5 0	87 10 0
Electrolytic	99 0 0	105 0 0
Tough	96 0 0	98 0 0
Best selected	98 0 0	100 0 0
Sheets	158 0 0	—
India	158 0 0	162 0 0
American electrolytic spot	103 0 0	104 0 0
Do. Aug.	103 0 0	104 0 0
Official average price cash, May		96 18 1½
Do. Three months, May		100 1 1½
Do. Settlement, May		96 17 3
Do. Electro. May		110 7 0
Do. B.S., May		109 5 0
Average spot price, copper, May		96 15 6
Do. Electro, May		109 5 0

Tin.

	£ s. d.	£ s. d.
Cash	214 15 0	245 0 0
Three months	246 15 0	247 5 0
English	242 0 0	243 0 0
Bars	244 0 0	245 0 0
Refined	—	—
Straits	—	255 0 0
Australian		249 10 0
Eastern		260 10 0
Banca		245 15 0
Official average price, cash, May		295 3 7½
Do. Three months, May		298 17 0
Do. Settlement, May		295 6 3
Average spot price, May		294 17 0

Spelter.

	£ s. d	£ s. d.
Ordinary	39 0 0	39 5 0
Remelted	35 0 0	36 0 0
Hard	27 0 0	28 0 0
Electro 99.0	45 10 0	46 0 0
English	42 0 0	42 10 0
India	37 0 0	—
Zinc dust 92-94%	85 0 0	90 0 0
Do. English	—	—
Zinc ashes, per cent. 70%	10 0 0	11 0 0
Official average price, May		46 0 9
Average spot price, May		45 1 9

Lead.

	£ s. d.	£ s. d.
Soft foreign (nst)		32 0 0
English		34 10 0
Official average price, May		39 3 2½
Average spot price, May		38 10 3

Antimony.

	£ s. d.	£ s. d.
English regulus	60 0 0	63 0 0
Chinese	46 0 0	47 0 0
Crude	40 0 0	41 0 0
Ore		Nominal.

Aluminium.

Virgin Metal 98/99—£ s. d.
per ton. 165 0 0

Phosphor Bronze.

Ingots.	Per ton.
Alloy No. I. or II.	—
III., IV., or V.	—
IV. or VII	—
VIII.	—
XI.	—
Cast Strips and Ingots	—

Castings.	Per lb.
I. or II.	—
III., IV. or V.	—
IV. or VII.	—
VIII.	—
XI.	—
No. VII., Chill, Cast, Solid	—
,, Cored Bars	—

Delivery 2 Cwt. free to any town.
10 per cent. Phosphor Copper price of best selected copper. .. £40 above
15 per cent. Phosphor Copper price B.S. .. £50 above
Phosphor Tin (5 per cent.) price of English Ingots. .. £30 above

Phosphor-bronze prices supplied by Charles Clifford and Son, Limited, Fazeley Street Mills, Birmingham.

*Chromium (Metallic).

98/99— purity, per lb. 7/6

*Nickel.

In cubes, 98/99— purity per ton £230 0 0

Nickel Silver.

per lb.
Ingots for raising .. .. 1/7 - 2/-
Ingots for Spoons and Forks .. 1/7 - 2/-
,, rolled to spoon size .. 1/10 - 2/3

*Tungsten Metal Powder.

per lb.
96/98— purity 3/10

*Molybdenum Metal.

96/98— purity, per lb .. .. —

*Cobalt Metal.

£ s. d
97— purity, per lb. 0 13 0

Quicksilver.

75 lb. bottle 20 0 0
* Net, delivered Sheffield Works.

Scrap Iron and Steel.

Cleveland.	s. d.	s. d.
Steel scrap, heavy melting	—	220 0
Iron scrap cast (cupola metal)	—	220 0
(London f.o.b.).		
Heavy steel		—
Light ,,		—
Heavy cast		—

Steel Scrap.

Without Analysis—	Per ton. £ s. d.
Heavy steel melting scrap	10 15 0
Steel planings, turnings and borings	9 15 0
Steel planings, turnings and borings mixed with wrought-iron or other material	9 10 0
Other classes of steel scrap, whether or not mixed	9 15 0
F.o.r. or in barge at nearest siding or wharf.	
With Analysis—	
Heavy steel melting scrap not over 0.04 per cent. p. and s.	11 0 0
Heavy steel melting scrap not over 0.05 per cent. p. and s.	11 0 0

Wrought-Iron Scrap.

	£ s. d.
(1) (a) W.I. plates and sections, not less than ¼ in. thick, reasonably clear of rivets, flanged ends, etc., suitable for shearing; cable scrap and chain scrap not less than ¼ in. dia.	11 5 0
(b) Heavy W.I. scrap not less than ¼ in. thick including horseshoes, rivets and bolts, and scrap therefrom	11 5 0
(c) W.I. scrap under ¼ in. thick, and all W.I. scrap not included in classes 1, 2 and 3.	11 5 0
(2) Mixed W.I. scrap	9 15 0
(3) Wrought-iron planings, turnings and borings mixed with steel or other materials	8 5 0
(4) W.I. planings, turnings and borings	8 7 6

Cast-Iron Scrap.

	£ s. d.
Heavy ord., broken, between 1½ cwt. and 10 cwt. each	10 5 0
Heavy machinery, broken between 1½ cwt. and 10 cwt. each	10 10 0
Cold blast, broken, between 1½ cwt., and 10 cwt.	11 15 0
Ingot mould, unbroken	11 0 0
Do. broken, between 5 cwt. and 2 tons each	11 5 0
Do. between 1½ cwt. and 5 cwt. each	11 10 0
Railway chairs, whole or broken for remelting	10 0 0
Heavy lumps, not exceeding 2 tons each	9 12 6
Light	9 5 0
Burnt, broken ready for cupola	8 10 0
Burnt fire bars	9 0 0
Turnings and borings, for iron and steel makers	10 0 0

Old Metal.

London—	£ s. d.
Copper (clean)	74 0 0
Brass (clean)	50 0 0
Lead (less usual draft)	26 0 0
Tea lead	24 0 0
Zinc	23 0 0
New aluminium cuttings	120 0 0
Braziery copper	60 0 0
Gunmetal	74 0 0
Hollow pewter	200 0 0
Shaped black pewter	105 0 0
(Above all d.d merchant's yard).	

Metallurgical Coke.

Durham and Northumberland—	£ s. d.
Blast furnace	3 2 9
Foundry	3 10 0
Lancs., Staffs., Yorks, Notts., Derbyshire, Lincolnshire and Midland Counties—	
Blast furnace	3 5 9
Foundry	3 17 9
F.o.t. at ovens.	